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Assessment of the 1980 4WX Herring Fishery

by

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Abstract

The definition of the portion of the total herring catch in 4WX which should be included in the assessment was reviewed. In contrast with previous assessments the $4X_b$ juvenile purse seine catches are included. The New Brunswick weir and shutoffs catches however were still excluded from the analysis. Finally the fixed gear catches in NAFO Subarea 463 were included.

The summer purse-seine landings were considered to underestimate the actual catch by approximately 40%. After correction the catches by the "adult fisheries" were estimated to have risen sharply to over 100,000 t after the historical low reported in 1979. The gillnet component exceeded 20,000 t, the highest recorded level. The juvenile fisheries in contrast experienced their worst year suggesting an extremely weak 1978 year-class. The catch from the adult fisheries was dominated by the large 1976 year-class. The poor juvenile fisheries were supported by the age 1 and 3 fish, the 1979 and 1977 year-classes respectively. Due to misreporting on the logs and market constraints the 1980 adult catch rates are interpreted as being unreliable. The 1980 juvenile catch rates indicate an exceptionally small 1978 year-class and an unexceptional 1977 year-class. The adult catch rates did not rise in relation to the qualitative industry information indicating an exceptional abundance of mature fish. The Bay of Fundy autumn larval survey data was analysed to provide an index of mature biomass. The time series was from 1972 to 1980.

Cohort analysis was "fine tuned" in relation to the best autumn larval survey index and juvenile catch rate indices (from N.B. weir data).

Two population options were presented, the only difference being the estimated sizes of the 1977 and 1979 year-classes. In the more optimistic option, which is considered the more realistic, the 1977 and 1979 year-classes are respectively 1.50 and 1.34 billion. The analysis indicates that the mature biomass (age 4+) has risen to approximately 350,000 t, the level estimated for the mid 70's. The resultant population estimates were used to estimate catchability (q) trends for the summer purse-seine fishery. After correction for the q changes, there was a good fit between the summer purse-seine catch rates (up to 1979) and fishable biomass. It is also noted that the 4+ biomass in 1978 and 1979 was below 100,000 t. Projections at $F_{0.1}$ indicate a yield 112,000 t in 1981 (using the more optimistic population estimate in 1980).

Résumé

Nous avons examiné comment avait été définie la portion des prises totales de hareng dans 4WX à être incluse dans l'évaluation. Contrairement aux évaluations antérieures, les prises de juvéniles à la senne coulissante dans $4X_b$ ont été incluses. Par ailleurs, les prises des parcs et des sennes-barrages du Nouveau-Brunswick ont encore été exclues de l'analyse. Enfin, les prises par engins fixes dans la sous-zone 463 de l'OPANO ont été incluses.

On est d'avis que les débarquements des senneurs en été ont sous-estimé d'environ 40 % les prises réelles. On a estimé que les prises dans les "pêcheries d'adultes", après correction, avaient augmenté abruptement à plus de 100 000 t après le creux historique signalé en 1979. Les prises des filets maillants dépassèrent 20 000 t, le plus haut niveau jamais enregistré. Par contre, les pêcheries de juvéniles connurent leur pire année, signe que la classe d'âge de 1978 serait extrêmement faible. Les prises dans les pêcheries d'adultes étaient dominées par l'importante classe d'âge de 1976. Celles des pêcheries de juvéniles, pauvres, étaient alimentées par des poissons d'âge 1 et 3, soit les classes d'âge de 1979 et 1977 respectivement. A cause de faux rapports de prises et de mauvaises conditions de marché, on a jugé que les taux de capture d'adultes n'étaient pas fiables. D'après les taux de capture des juvéniles en 1980, la classe d'âge de 1978 est exceptionnellement faible et celle de 1977 normale. Les taux de capture des adultes ne se montrèrent pas à la hauteur des rapports qualitatifs de l'industrie, à l'effet que les poissons matures étaient exceptionnellement abondants. Les données des relevés larvaires d'automne dans la baie de Fundy ont été analysées dans le but d'obtenir un indice de biomasse mature. La série couvre les années 1972-80.

On a fait un ajustement précis de l'analyse des cohortes en relation avec le meilleur indice du relevé larvaire d'automne et les indices des taux de capture des jeunes (à partir des données des parcs du N.-B.).

Deux états de population ont été présentés, différant seulement par l'importance estimée des classes d'âge de 1977 et 1979. Dans le cas le plus optimiste, et le plus réaliste à notre avis, les classes d'âge de 1977 et 1979 sont respectivement de 1,50 et 1,34 milliard de poissons. L'analyse indique que la biomasse des sujets matures (âge 4+) a augmenté à environ 350 000 t, le niveau estimé des années 1970. Les estimations de populations qui en résultent ont été utilisées pour calculer les tendances du potentiel de capture (q) des sennes coulissantes dans la pêche d'été. Après correction pour tenir compte des changements de q, on a observé un bon accord entre les taux de capture des sennes coulissantes en été (jusqu'en 1979) et la biomasse pêchable. On a noté également que la biomasse de 4+ en 1978 et 1979 était inférieure à 100 000 t. Les prévisions à $F_{0,1}$ indiquent un rendement de 112 000 t en 1981 (avec l'estimation de population la plus optimiste en 1980).

Problems with stock definition

There has continually been a problem in defining that proportion of the total catch in 4WX which should be included in the analytical assessments. It is assumed that to a large degree a unit stock, in the biological sense, is being assessed (i.e. the major stock with spawns off south-west Nova Scotia). It is nevertheless recognized that the smaller "local" stocks in the immediate area - e.g. the Scotts Bay and Grand Manan stocks - are subsumed in this management unit. Also, although there is thought to be some intermixing of the two other major stocks in NAFO SA 5 and 6 within the 4WX fishery (either in the juvenile nursery grounds or during summer feeding) the degree of mixing has not been estimated. To partially circumvent the mixing problem, a major portion of the juvenile catches in 4X(b) have not been included in past assessments (except for the 1972 and 1973 "Grand Manan" purse-seine catch). The details, and the justification, of the 4WX catch included in the management unit are given in Sinclair and Iles, 1980. The results of the population analyses in recent assessments, however, have been rather unsatisfactory; due both to the variation in the proportion of the juvenile catch included and to the strong temporal trend in the magnitude of the 4X(b) mobile gear juvenile fishery. For example, the 1970 year-class has been consistently estimated to be larger than the earlier, very strong year-classes (1963 and 1966) which were heavily fished as juveniles. Also the fine tuning of the cohort analyses using catch rate data from both the N.B. weirs and the purse-seines has been difficult. Clearly the year-class strength time series from the cohort analyses, given the trend in juvenile catch not included in the analyses, are highly suspect. In the previous two assessments an attempt has been made to generate a more realistic year-class strength time series by including a portion of the 4X(b) catches. The result could not be easily translated into quota advice because of the subsequent need for a N.B. weir allocation. In this assessment a different approach is taken. As in the "traditional" stock definition the N.B. weir and shutoffs are not included. The total 4X(b) purse-seine catch, predominantly by the "brit" fishery is, however included. The "brit" fishery prosecutes predominantly recently metamorphosed fish aggregated off St. John. There is good evidence to conclude that these fish come from the "S.W. Nova Scotia" larval population and thus should be included in the management unit. Their inclusion will be shown to result in a more satisfactory year-class strength time series (and a tighter relationship with historical weir and purse-seine catch rates) without causing problems in subsequent quota allocation to a new gear type. In addition the relatively large catch by gillnets in NAFO subarea 463 is included in this analysis. A high catch in this area has only occurred in 1980, and is in a contiguous area to the "traditional stock" area.

Catch Description

The seasonal timing of the various components of the overall 4WX herring fishery are shown in Figure 1, and their geographical location shown in Figure 2. Both juveniles and adults are being (or have been) fished during all seasons, and at each phase of the adults annual migration. The best estimates of landings by gear type for the 1980 fishery are given in Table 1. A consistently reported estimate of the degree of under reporting by the 4Xa purse-seine fishery is 40 (from fishermen, processors and port sampler interviews). The sociological reasons for the breakdown in the reporting scheme as well as the methods used are described by Kearney (1981). The catch by this gear component has been appropriately adjusted upwards. The gillnet catches reached their highest recorded level at close to 20,000 t. The allocations and quotas for gear components concentrating on adult fish were considerably exceeded. In contrast the catch of juveniles in the

weir and shutoffs reached an historical low suggesting an extremely weak 1978 year-class. There was again, for the third year, a lucrative trap fishery in Liverpool Bay which was arbitrarily shut down at close to 2,000 t. This fishery has prosecuted almost exclusively the large 1976 year-class, which supports the previous conclusion that the fishery has been supported by a presumably ephemeral expansion of geographical range. The historical catch trends are shown in Table 2 and Figures 3, 4 and 5. The total catch by the new stock definition for 1980 (column M in Table 2) has risen sharply after the historical low of 1979.

Biological sampling and catch recording

The 4WX herring catches by all gear components have again been well sampled. This is reflected in the catch-to-sample ratios for 1977 and 1980 in Table 3. The "area of catch" reporting system by the purse-seine fleet, which broke down during the 1979 summer fishery, seems to be functioning again. The above mentioned misreporting of landings however raises a more serious problem.

The length frequency samples were matched with catch-by-area generally on a monthly basis. The "areas" used for two gear components are shown in Figures 6a and 6b. Age length keys were done on a monthly basis where possible and again, if appropriate, on a gear component basis (e.g. separate age length keys for the N.B. weirs versus N.S. weirs). As good as the biological sampling has been, the accuracy of the generation of numbers-at-age has been seriously undermined by the misreporting of purse-seine landings. This problem deserves immediate consideration by the Atlantic Small Pelagics Management Committee.

Age composition

The overall age composition of the catch of the various components of the fishery are shown in Table 4 and Figure 7. The catches for the 1970 and 1971 year-classes have been adjusted in accordance with the criteria adopted by Stobo et al. 1978. The adjustment is deemed necessary due to an ageing problem for the 1970 year-class. The adult fisheries were dominated, as predicted, by the 1976 year-class (age 4 fish). The 1970 year-class (assuming the adjustment is valid) is still contributing to the fishery as age 10, about 9 million fish being taken. The 1978 year-class is almost non-existant (by far the lowest number of age two fish taken by the weirs of any previous year-class). In excess of a quarter of a billion one-year olds (1979 year-class) were taken in 4X(b) during 1980. This N.B. weir catch on one year olds was the second highest since the 1963 year-class, being exceeded only by the 1970 year-class in 1971. There are some interesting differences in age composition by area and month that are not reflected in the combined age compositions. The Scotts Bay purse-seine fishery on spawning aggregations, for example, had a markedly more balanced adult age structure. This further suggests the biological integrity of this spawning group. The overall percentage age composition for the stock and for the 4WX total are shown in Figure 8. The dominance of the 1976 year-class and the very low percentage of age 2 and age 5+ fish is striking.

Effort and catch rates

Associated with the misreporting of landings by the purse-seine fleet there was inaccurate recording of catch rates on the log records (in order to show consistent data with the landings on the purchase slips). This breakdown in the log

record accuracy must be considered in evaluating the 1980 catch rate data. The temporal trends in catch rates for various gear components are shown in Table 5. The juvenile gears catch rates declined markedly in 1980 paralleling the drop in catches. The purse-seine catch rates did not increase strongly in response to the 1976 year-class entering the adult fishery. The market influences and the misreporting practices (Kearney 1981) no doubt influenced the catch rates. The 1980 gillnet fishery catch rates which were also influenced by the market constraints did rise, but not to the level of 1977 (the first year of this short-time series). In sum, due to the specific complications of the 1980 fishery the adult fishery catch rate data are interpreted as being unreliable. The various catch rate time series up to 1979, however, still contain valuable information.

In the past two assessments (Sinclair et al. 1979b, Sinclair and Iles 1980) the question of changes in catchability in the purse-seine fishery due to stock size fluctuations, and increases in efficiency by the fleet, were considered in some detail. The importance of catchability changes by the purse-seine fleet are pursued further in this assessment. The winter and the summer purse-seine catch rate time series are compared in Figure 9. The 1972 and 1973 points appear to be outliers. This can be plausibly interpreted as a response to the effort directed to the exceptionally large 1970 year-class by the summer purse-seine fishery. At that time there was an unlimited market for juveniles in the meal fishery. In an attempt to construct a reasonably consistent time series on adult fish these two outliers were corrected by eye in relation to the relationship indicated in Figure 9. It is the longer summer purse-seine catch-rate time series (1967 to 1980) which is more useful to help key in the cohort analysis.

In sum the 1980 juvenile catch rates indicate an exceptionally small 1979 year-class and an unexceptional 1977 year-class (three year olds, if from a very large year-class, would have been able to sustain the weir fisheries). The adult fishery 1980 catch rates did not rise in relation to the qualitative industry information indicating an exceptional abundance of mature fish.

Autumn larval survey - "Relative spawning estimates"

A variety of estimates of larval abundance are shown in Table 6. A large proportion of the 1975 survey was not completed. Thus, for all but one method this year is interpolated. The station locations are shown in Figure 10. The details of the survey methodology are given in Sinclair et al. 1979a. There are good reasons for concluding that the survey covers the major part of the larval distribution for this management unit (one major and two minor biological stocks) to the exclusion of other contiguous spawning stocks (Gulf of Maine and Georges Bank), Figure 11. The geometric mean larval abundance has been shown to be the best estimation of spawning stock size (O'Boyle, pers. comm.) for this survey, and was chosen to help key in the cohort analysis.

Population Size

The catch matrix for the 4WX stock as well as the new additions are shown in Table 7. A partial recruitment vector is difficult to estimate for this fishery because of the constant state of flux in markets, combined with dramatic year-class strength variability (and associated changes in fish size). The historical averaging method is suspect because of the strong temporal trends, as well as the observed between year variability for the years 1973 to 1977. There are some guidelines however. There is good evidence for full recruitment by age five and some evidence for a reduction in availability of age 3 fish (not every year). The

following partial recruitment vector was somewhat arbitrarily selected to initiate the analysis.

	AGE									
	1	2	3	4	5	6	7	8	9	10
PR.	0.01	0.80	0.60	0.90	1	1	1	1	1	1

The partial recruitment of two and three year olds are higher than in previous assessments but the stock definition has been slightly charged with the inclusion of the 4Xb purse-seine catches. The terminal fishing mortalities were defined by iteration, averaging the age 4 to 7 fishing mortalities. The "not fishing complete" equation was used for the cohort analysis.

The fishing mortality-at-age for 1980 was defined initially in relation to the larval survey time series (1972 to 1980). A mature F of 0.32 (times the above PR vector) gave a reasonable fit between mature biomass and autumn larval abundance (Tables 8, 9 and Figure 12). A mature F value of 0.30 put the 1980 mature biomass considerably higher than indicated by the larval abundance. A higher starting F vector would give a marginally better fit to the larval data but results in an estimate of the 1976 year-class which is not consistent with independent estimates. The mature F 0.32 option, with the above PR vector, indicates the following recent year-class strengths.

Year-class	Abundance ($x10^{-9}$) at age 2	"N.B. weir" predicted abundances at age 2
1976	3.98	4.92
1977	0.75	1.78
1978	0.47	-0.90

In Figure 13 the relationship between estimated year-class strength at age 2 and N.B. weir catch rates is shown (1966 to 1975 year-classes). The N.B. weir catch rate index is the numbers of a year-class caught at age 2 by N.B. weirs divided by the number of active weirs in the appropriate year. The cumulative fishing mortalities shown in Table 9 indicate that the 1966 to 1975 year-class strengths-at-age 2 should be relatively insensitive to the initial starting conditions. The G.M. regression predicts higher year-class strengths than estimated from the cohort analysis with the above described starting condition. It was not felt justified however to use the precise "N.B. weir" predicted values, because of the mixing problems in this gear component (Gulf of Maine and S.W. Nova Scotia juveniles are both caught by these weirs). The Gulf of Maine 1977 year-class appears to be very strong in the U.S. fishery. It did not however show a parallel strength in 4WX fisheries. How much of the relative differences in inferred year-class strength between areas that may be explained by rapid expansion of juvenile effort in the USA is difficult to determine.

The 1979 year-class strength also looks promising, ranking second in numbers caught-at-age 1 in N.B. weirs. The relationship between cohort analysis estimates and catch rates is not, however, predictive (Figure 14).

In sum, there is evidence that the 1976 year-class is very large, that the 1977 year-class is of moderate size and that the 1978 year-class is the worst on record. The only evidence for the 1979 year-class is that it is of moderate strength.

The cohort analysis in Table 8 estimates the 1977 year-class at 0.75 billion

at age 2. If it is set at 1.5 billion at age two (which is below the N.B. weir catch rate prediction) the fishing mortality on the year-class at age 3 in 1980 was 0.072 and the partial recruitment 0.23. In the second option in Table 8 the 1977 year-class is set at this level and the 1979 year-class strength at age 1 (GM 1964 to 1975), 1.34 billion. This option agrees better with the weir catch rates but infers a very low fishing mortality at age 3 in 1980, but one that is similar to that estimated for the 1976 year-class in 1979 (age 3).

Even though the 1980 summer purse-seine catch rate estimate is inappropriate for keying in the 1980 fishing mortality the rest of the time series is useful. Prior to its use, temporal changes in catchability were evaluated. Fishing mortality (F) per unit of effort (E) was calculated using the catch equation. The purse-seine catch-at-age and the population matrix (Table 8), for the relevant years for which there are data available on CPUE for the fleet, provided the input data for the calculation of F-at-age. A mean fishing mortality (ages 4 to 10) weighted by population numbers was estimated for each year and divided by effort (catch by purse-seine fleet/CPUE). The derived estimates of FUE or q are shown in Table 10 and Figure 15. The analysis (as already indicated Sinclair et al 1979b and Sinclair and Iles 1980) suggests marked changes in catchability with time.

The CPUE values, corrected for the q changes, are plotted in Figure 16 in relation to fishable biomass (50% of age 3 and 4+ numbers times mean weight-at-age). Except for the years when the very large year-classes are three years old (1969, 1973 and 1979) there is a tight relationship. The catch rates in 1969 and 1973 are higher than fishable biomass indicates, whereas in 1979 the catch rate is relatively depressed in relation to the estimated fishable biomass. The different directions of the outliers from the relationship are reasonable, given the recent changes in market demand for small fish.

When CPUE values are not corrected for q changes there is a clear downward trend in the absolute value of the catch rate standard (Figure 17). For example 40 t/set can represent from 600,000 t to 300,000 t depending on the time period. The good fit indicated in Figure 16 suggests that the input parameters affecting mature biomass for the cohort analysis are consistent with the temporal trends in catch rates. The poor relationship in Figure 17 underlines that caution is necessary when using a purse-seine catch-rate standard.

The 1+ and 4+ biomasses for options A and B are plotted in Figure 18. Both options indicate a healthy mature biomass in the summer of 1980. (The only difference being in the estimated sizes of the 1979 and 1977 year-classes.) A second point to note is the very low 4+ biomass in mid 1978 and 1979 (< 100,000 t). If the 1976, 1977 and 1979 year-classes are as strong as indicated by the N.B. weir catch rates Option B (which is still considered a conservative estimate) indicates that 1+ biomass has rebounded to the levels estimated during the mid 70's.

Yield per recruit

As requested during the recent CAFSAC meeting on assessment methodology the difference between "average" conditions and the "immediate" conditions on $F_{0.1}$ values was evaluated. Using the following PR vector

AGE	1	2	3	4	5	6	7	8	9	10
PR	0.0	0.8	0.6	0.9	1	1	1	1	1	1

and both the mean July weights (1969 to 1978) and the 1980 mean weights for the fishery (Table 12) generated values of respectively 0.24 and 0.25.

A change in the PR vector had a much more pronounced effect. The 1980 fishery weights-at-age and the following vector (which appears more representative of the most recent years 1978 to 1979) were run.

AGE	1	2	3	4	5	6	7	8	9	10
PR	0.006	0.40	0.23	0.90	1	1	1	1	1	1

The partial recruitments for age 1 and 3 are consistent with the year-class strengths "fixed" in option B (1.5 billion for 1977 year-class at age 2 and 1.34 billion for the 1979 year-class at age 1). The partial recruitment value at age 2 is arbitrarily set slightly higher than that at age 3 (as frequently observed). These conditions provide a $F_{0.1}$ value of 0.293.

Projections

The following input parameters were used in the five year projections:

Option A

(i) weight-at age (means from 1967 to 1979, July), Table 12

(ii) partial recruitment which gave the lower $F_{0.1}$ values

(iii) catch-at-age for 1980 as in Table 7

(iv) population numbers-at-age (for January 1, 1980) for Option A, Table 8

(v) recruitment equal to 1.34×10^9 (geometric mean for 1965 to 1980, option A population matrix)

(vi) $F_{0.1}$ equal to 0.249

Option B

As above except for Option B population numbers-at-age and $F_{0.1}$ equal to 0.293.

The detailed five year projections are shown in Table 11 and Figure 19. The more optimistic population status and lower partial recruitment at age generates a 1981 catch of 112,000 t, the less optimistic 79,000 t. Given that the 1976 year-classes maximizes its biomass during the coming fishing season and that the recent year-class strengths (1976, 1977 and 1979) have been set at conservative levels even in option B, the higher $F_{0.1}$ yield is perceived as being the more realistic.

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Table 1. Provisional catch (t) during 1980 4WX herring fishery

	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
4W															
Purse seine ("Chedabucto Bay")	165	665	8128												8958
4Xa															
Purse seine (reported landings)							(327)	(7410)	(19289)	(15913)	(2015)	(32)			(44986)
(landings adj. for misporting)							545	12350	32148	26522	3358	53			74976
Gillnet ("stock")					13	2	6	1079	996	7416	4945	795			15252
Gillnet (463)					8	54	17	2455	1339	448	218	4	9		4552
Weir							69	648	1271	395					2383
Trap (Liverpool)					← 2010 →										2010
4WXa total	165	665	8128		1021	1066	637	16532	35754	34781	8521	852	9		108131
4Xb															
Purse seine				← 787 →								32	155	469	1443
Weir and shut-offs							37	119	1734	5622	2415	958	215		11100
Shut-offs									116	818	469	670	352		2425
4Xb total				787			37	119	1850	6440	2884	1660	722	469	14968

Table 2. Annual 4WX herring catch by different components of the fishery (tonnes)

YEAR	4W		4X$_a$					4X$_b$				4WX Foreign total	Grand total	
	Purse Seine[a]	Fixed Gear[b]	Summer Purse Seine	Gill[14] Net	Weir	Liverpool Trap	Fixed Gear Non-Stock[b]	Winter Purse Seine: Grand Manan	Winter Purse Seine: Saint John	Weir	Misc & Shut Offs			
1961	-		15093[5]	2955[5]	5345[5]	-		-	6871[5]	28203[5]	1161[5]			a winter catch, Nov. Apr. is put into latest calender year
1964	-		24894[5]	4051[5]	12458[5]	-		-	15991[5]	27337[5]	2095[5]			
1965	-		54527[5]	4091[5]	12021[5]	-		-	15755[5]	31684[5]	1662[5]		86994[16]	
1966	-		112457[5]	4413[5]	7711[5]	-		-	25645[5]	35601[5]	204[5]		150226	b fixed gear catch not considered part of major 4WX migratory stock
1967	-	411	117382[5]	5398[5]	12475[5]	-		-	20888[5]	29912[5]	100[5]	598[7]	156741	
1968	-	375	133267[5]	5884[5]	12571[5]	-		-	42223[5]	32114[5]	1031[5]	2417[7]	196362	
1969	25112[6]	343	84525[5]	3474[5]	10744[5]	-		-	13202[5]	25646[5]	893[5]	13405[5]	150462	
1970	27107[6]	151	70849[5]	5019[5]	11706[5]	-		-	14749[5]	15073[5]	767[5]	60952[9]	190382	c estimate of annual catch incorporated into 1980 catch at age matrix (columns A+C+D+E+F+H+I+J+K)
1971	52535[6]	169	35071[5]	4607[5]	8081[5]	-		-	4868[5]	12139[5]	521[5]	23939[9]	129101	
1972	25656[6]	330	61158[5]	3789[5]	6766[5]	-		32153[5,c]	21[5]	31995[5]	704[5]	23906[10]	154449	
1973	7921[6]		36618[5]	5205[5]	12492[5]	-		25155[5,c]	2167[5]	19088[5]	847[5]	32702[10]	122260	
1974	27107[6]		76859[5]	4285[5]	6436[5]	-		-	10131[5]	19028[5]	1574[5]	24483[10]	149101	
1975	27030[6]		79605[6]	4995[6]	7404[6]	-		-	1152[6]	30819[6]	7	23711[10]	143897	
1976	37196[1]		58396[1]	8322[1]	5959[1]	-		94[6]	746[6]	29206[6]	7	4133[1]	114846	
1977	23251[1]	1138	68538[1]	18523[1]	5211[1]	-		-	1216[1]	30697[1]	2790[1]	410[1]	117171	
1978	17274[1]		57973[13]	6059[13]	8057[13]	-		3832[13]	2687[13]	33570[13]	5272[13,11]	-	95682	
1979	14073[13]		25265[7]	4363[7]	9307[7]	2174[15]		2973[7]	220[7]	32477[7]	5351[7,11]	-	58375	
1980	8958[2]		74976[17,18]	19804[17,18]	2383[17]	2010[15]		656[15]	787[15]	11100[17]	2425[17,11]	-	109574	
1981	16422[2]													
	A	B	C	D	E	F	G	H	I	J	K	L	M	

[1]Stobo et al. CAFSAC Res. Doc. 78/25

[2]"Best estimate", provisional

[3]Miller & Stobo, CAFSAC Res. Doc. 77/11

[4]Stobo, ICNAF Res. Doc. Doc. 75/99

[5]Miller & Iles, FRB Tech. Rep. 594

[6]"Catch at age" printouts

[7]St. Andrews provisional catch statistics, March 1980

[8]Grand Manan catch incorporated into previous assessments catch-at age matrix

[9]Miller, ICNAF Res. Doc. 73/95

[10]ICNAF Stat. Bull.

[11]Shut-offs only

[12]Sinclair et al. CAFSAC Res. Doc. 79/19

[13]Gillnet catches in Stat. districts 32-44

[14]Statistics Branch

[15]Catch matrix starts in 1965

[16]St. Andrews provisional catch statistics, March 1981

[17]Adjusted upwards assuming 40% misreporting

[18]Includes area 463 catch

Table 3. Temporal distribution of catch to sample ratio for 4WX herring fishery (1977 to 1980).

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Purse Seine												
4X 1977	-	-	-	-	382	72	184	112	109	160	130	107
4X 1978	-	-	-	-	139	598	498	157	294	164	-	-
4X 1979	217	123	-	-	4	222	140	182	396	389	40	-
4X 1980	←	394	→	-	←	209	→	316	455	682	← 94 →	235
4Wa 78/79	220	-	-	-	-	-	-	-	-	-	-	226
4Wa 79/80	220	-	-	-	-	-	-	-	-	-	-	118
Gillnet												
1977	-	-	-	-	348	271	1118	462	945	-	-	-
1978	-	-	-	-	21	116	114	305	219	-	-	-
1979	-	-	-	-	←	481	→	188	378	→	-	-
1980	-	-	←			519	778	492	663	→	-	-
N.S. Weirs												
1977	-	-	-	-	366	127	1021	1144	50	15	-	-
1978	-	-	-	-	176	200	212	95	22	51	239	28
1979	-	-	-	-	64	126	127	73	-	111	15	-
1980	-	-	-	-	←	120	→	212	99	-	-	-
Liverpool Fishery												
1978	-	-	171	-	-	-	-	-	-	-	-	-
1979	-	-	50	-	-	-	-	-	-	-	-	-
1980	-	-	155	-	-	-	-	-	-	-	-	-
N.B. Weirs & Shut-offs												
1977	-	-	-	-	-	42	136	93	110	169	123	107
1978	-	-	-	-	17	43	148	114	236	270	-	132
1979	286	52	-	-	14	51	97	228	155	132	142	37
1980	-	-	-	-	37	40	103	124	288	126	283	-

Table 4. Catch at age (x 10^{-3}) by year for the 1980 4WX herring fishery

	Age 1	2	3	4	5	6	7	8	9	10	11+	TOTAL NUMBERS	TONNES
4Wa													
Purse-seine	0	51	18493	33266	1257	603	1458	2739	3696	2399	1803	65265	8958
4Xa													
Purse-seine	978	335	30995	357030	19976	1920	1960	1393	1980	758	428	417703	74976
Liverpool	0	8	1706	18583	393	27	30	3	33	39	0	20819	2010
Gillnet "stock"	0	0	233	66015	5786	957	380	574	558	299	141	74943	15252
463	0	0	49	12451	2323	836	382	754	970	358	233	18356	4552
Weir	31	3031	14218	7752	186	8	81	48	81	4	0	25440	2383
4WXa total	1009	3425	65694	495097	29921	4351	4291	5508	7268 (2248)*	3857 (8877)*	2105	622526	108131
4Xb													
Purse-seine	1005	6275	7263	7199	27	0	0	0	0	0	0	21769	1443
Weir and	208920	3320	48245	18762	833	89	106	54	17	10	0	280356	11101
Shut-offs	49075	2005	13842	2853	91	36	18	13	40	53	0	68026	2425
4Xb total	259000	11600	69350	28814	951	125	124	67	57	63	0	370151	14969

* adjustments made in the relative proportions of the 1970 and 1971 year classes (see text for justifications).

Table 5. CPUE trends for various components of the 4WX herring fishery

	Purse Seine		Fixed Gear		
	4Xa[1]	4Wa[1]	Gillnets[6]	N.S. Weirs[7]	N.B. Weirs[7]
1965	-	-		481	162
1966	-	-		308	193
1967	55.5[5]	-		499	153
1968	52.8[5]	-		503	165
1969	41.7[5]	-		430	132
1970	39.0[5]	-		468	77
1971	32.6[5]	-		323	62
1972	45.0[5]	74.5[3]		271	164
1973	49.1[5]	73.6[3]		500	98
1974	45.2[2]	144.1[2]		257	98
1975	50.9[2]	146.3[2]		296	158
1976	44.6[2]	127.4[2]		238	150
1977	37.4[2]	100.3[2]	4.2	209	157
1978	39.5[2]	85.7*	1.6	269	150
1979	31.7[2]	71.0[2]	2.1	332	142
1980	28.5*[2]	68.2*[2]	3.0	85	48
1981		76.1*[2]			

[1]Catch per successful night

[2]Re-analysis of logs

[3]Stobo, ICNAF Res Doc 75/39

*Interpolated (see text for rational)

[5]Stobo et al, CAFSAC Res Doc 78/25

[6]t/purchase slip (areas 32 to 37)

[7]t/year

*Misreporting and/or avoidance of large sets

Table 6. 4WX larval herring abundance indices

	Mean Weighted on area (82 Stations)	Mean Weighted on area (115 Stations)	Arithmetic mean	Geometric mean
1972	8.36	8.31	7.24	2.64
1973	4.99	5.59	5.27	2.30
1974	30.85	43.30	37.49	7.60
1975	10.93	27.71*	24.56*	6.02*
1976	11.95	12.12	11.62	4.44
1977	4.92	5.01	4.57	1.83
1978	1.91	4.39	3.51	1.24
1979	3.92	6.61	6.32	2.18
1980	21.06	20.52	19.48	4.61

* interpolated

Table 7. New catch matrix for the 4WX herring stock (and the difference from the traditional stock matrix)

Catch Matrix

CAT	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	270378	154323	722208	164703	108875	699720	87570	0	754	14151	0	0	0	0	311	2014
2	1084719	914093	613970	2389061	290329	576896	404224	649254	126421	596153	264491	48470	140494	346719	170523	9700
3	34835	448940	153626	224956	531812	76532	183896	71984	595992	72381	180898	176226	28659	36177	226442	72957
4	234383	73382	266454	83109	132319	286278	106630	148516	109530	616622	92487	130598	192958	11338	47200	502296
5	49925	321857	110051	290285	162439	201215	113566	77207	34422	53199	383650	72334	106061	107627	4639	29948
6	10592	45916	159203	73087	112631	120200	75593	75384	25562	15254	50599	219788	35066	60431	19695	4351
7	1693	13970	57948	90617	62506	111937	93620	49065	19361	8120	9357	18960	150588	27286	15521	4291
8	561	7722	4497	31977	22595	41257	50022	48700	17604	5313	3238	4967	12466	96741	9981	5508
9	54	1690	409	15441	6345	21271	36618	26055	19836	10964	3481	3556	2873	9838	35386	2248
10	37	215	296	5668	2693	7039	7536	13792	9661	5787	2842	1835	1253	2169	3834	8077

Changes from Previous Matrix

CATAPP																
1	270378	154323	722208	164703	108875	699720	87570	0	754	14151	0	0	0	0	157	0
2	873923	870463	566022	1837355	219793	469980	260057	0	96765	477852	28901	28548	84860	232550	65273	0
3	8385	178872	85196	145023	147345	18366	10234	0	33376	26781	21957	14589	9191	14132	43493	0
4	2236	14791	28060	18002	13359	917	460	0	0	416	131	1	135	697	1444	0
5	173	13082	237	15767	1716	118	5	0	0	0	4	0	0	97	22	0
6	0	437	0	260	1779	57	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MEAN WEIGHT OF INDIVIDUALS IN CATCH 18/ 3/81

I	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	0.06	0.10	0.08	0.08	0.13	0.10	0.14	0.12	0.13	0.12	0.15	0.18	0.19	0.15	0.13	0.17

MEAN AGE OF INDIVIDUALS IN CATCH 18/ 3/81

I	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	2.26	3.87	2.60	2.65	3.49	2.96	3.76	3.49	3.50	3.22	3.85	4.51	4.62	4.04	3.55	4.06

Table 8. Estimated population numbers at age for 48A herring

OPTION A

POPULATION NUMBERS

	65	66	67	68	69	70	71	72	73	74	75	76
1	3510358	2735609	6145384	1263588	1728879	2182739	6196472	1009647	1955876	1432764	194319	611451
2	3871007	2629390	2100090	4369747	885509	1316972	1153942	4994065	826138	1600490	1160243	159095
3	989355	2187818	1325657	1163865	1415935	462293	556249	579011	3501276	561994	770949	710605
4	1325750	778495	1385016	946349	749344	678066	309244	289022	408920	2327327	394629	467516
5	342492	873354	570979	892858	699605	493783	296118	156705	102248	235689	1347511	239409
6	95011	235235	423813	367900	468349	425807	222209	139682	58439	52568	144829	756108
7	49684	68704	151048	202936	235079	281539	239788	113530	46152	24717	29236	72792
8	4395	39146	43200	71234	84157	135909	129220	111611	48555	20267	12889	15470
9	1729	3091	25063	31300	29387	48457	73942	60535	47314	23824	11786	7623
10	310	957	1001	20150	11655	18319	20426	27405	25986	20789	9585	6500
1+	10189591	9551299	12161252	9329927	6307899	6043884	9197610	7480553	7020705	6300428	4075977	3046570
2+	6679233	6815690	6025868	8066340	4579020	3861146	3001138	6471506	5065029	4867664	3881658	2435119
3+	2808226	4186301	3925778	3696593	3693511	2544173	1847196	1477501	4238891	3267175	2721415	2276024
4+	1818872	1998482	2600121	2532727	2277576	2081881	1290947	898490	737614	2705180	1950466	1565419

	77	78	79	80	81
1	4857521	915399	57974	695484	1337475
2	500613	3977002	749465	47184	567595
3	86399	282743	2942369	459315	29906
4	422339	44805	198756	2204115	310361
5	264600	171186	26425	120020	1353002
6	130561	120668	42770	17437	71354
7	429177	57069	44114	17197	10367
8	42442	207754	22034	22074	10224
9	8171	23469	82660	9009	13123
10	3023	4091	10313	35575	5356
1+	6735846	5804185	4176781	3627409	
2+	1878325	4888786	4118807	2931925	
3+	1377711	911785	3369342	2884741	
4+	1291313	629041	426972	2425427	

OPTION B

	78	79	80	81
1	1832104	57974	1337082	1337475
2	3977002	1500000	47184	1192891
3	282743	2942369	1162252	29906
4	44805	198756	2204115	885746
5	171186	26425	120020	1353002
6	120668	42770	17437	71354
7	57069	44114	17197	10367
8	207754	22034	22074	10224
9	23469	82560	9009	13123
10	4091	10313	35575	5356

Table 9. Estimated fishing mortalities-at-age and the cumulative fishing mortality for individual cohorts for 4WX herring (1965 to 1980).

FISHING MORTALITY 18/ 3/81

I	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	0.089	0.064	0.139	0.156	0.072	0.437	0.016	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.006	0.003
2	0.371	0.485	0.390	0.927	0.450	0.662	0.490	0.155	0.185	0.530	0.290	0.411	0.371	0.101	0.290	0.256
3	0.040	0.257	0.137	0.240	0.536	0.202	0.455	0.148	0.208	0.154	0.300	0.320	0.457	0.152	0.089	0.192
4	0.217	0.110	0.239	0.102	0.217	0.628	0.480	0.839	0.351	0.346	0.300	0.369	0.703	0.328	0.304	0.288
5	0.176	0.523	0.240	0.445	0.297	0.598	0.551	0.786	0.465	0.287	0.378	0.406	0.585	1.187	0.216	0.320
6	0.131	0.243	0.536	0.248	0.309	0.374	0.472	0.907	0.661	0.387	0.488	0.388	0.628	0.806	0.711	0.320
7	0.038	0.257	0.552	0.680	0.348	0.579	0.565	0.649	0.623	0.451	0.437	0.339	0.504	0.752	0.492	0.320
8	0.152	0.246	0.122	0.685	0.352	0.409	0.558	0.658	0.512	0.342	0.325	0.438	0.392	0.724	0.694	0.320
9	0.050	0.927	0.018	0.788	0.273	0.664	0.793	0.646	0.622	0.711	0.395	0.725	0.492	0.622	0.642	0.320
10	0.141	0.283	0.392	0.369	0.293	0.545	0.517	0.794	0.522	0.364	0.393	0.370	0.603	0.860	0.522	0.320
5+	0.153	0.446	0.373	0.446	0.311	0.510	0.555	0.752	0.556	0.345	0.389	0.391	0.542	0.876	0.576	0.320

age	1965 FROM FISHPORT									1975					
1	3.693	4.247	5.420	4.838	5.107	4.077	3.680	3.439	3.404	3.543	1.731	1.148	0.478	0.482	0.262	0.003
2	3.926	3.604	4.183	5.281	4.683	5.034	3.640	3.664	3.439	3.404	3.532	1.731	1.148	0.478	0.482	0.256
3	2.981	3.555	3.120	3.792	4.354	4.233	4.373	3.150	3.509	3.253	2.873	3.241	1.320	0.777	0.377	0.192
4	3.490	2.941	3.298	2.982	3.552	3.818	4.031	3.918	3.002	3.301	3.100	2.573	2.921	0.864	0.624	0.288
5	2.473	3.272	2.831	3.059	2.880	3.335	3.189	3.551	3.079	2.651	2.954	2.800	2.204	2.218	0.536	0.320
6	1.591	2.298	2.749	2.591	2.614	2.584	2.736	2.638	2.764	2.613	2.364	2.577	2.394	1.619	1.031	0.320
7	0.671	1.459	2.055	2.213	2.343	2.305	2.210	2.265	1.731	2.104	2.227	1.876	2.189	1.766	0.812	0.320
8	1.471	0.633	1.203	1.503	1.533	1.995	1.726	1.645	1.616	1.108	1.653	1.790	1.537	1.685	1.014	0.320
9	0.533	1.319	0.587	1.081	0.818	1.181	1.587	1.168	0.987	1.104	0.766	1.328	1.352	1.144	0.962	0.320
10	0.141	0.283	0.392	0.369	0.293	0.545	0.517	0.794	0.522	0.364	0.393	0.370	0.603	0.860	0.522	0.320

Table 10. Distribution of CPUE, EFFORT and catchability (q) for the 4Xa purse-seine fishery from 1967 to 1979

Year	CPUE (4Xa)[1]	CATCH (4Xa)	EFFORT	Catchability (q)[5]	Normalized Catchability[2]	Adjusted EFFORT[3]	Adjusted CPUE[4]
1967	55.5	117382	2115	12.4	0.909	1959	61.1
1968	52.8	133267	2524	11.0	0.806	2034	65.5
1969	41.7	84525	2027	7.0	0.513	1040	81.3
1970	39.0	70849	1817	10.3	0.755	1372	51.7
1971	32.6	35071	1076	10.7	0.784	844	41.6
1972	34.0	61158	1799	13.8	0.011	1819	33.6
1973	33.0	36618	1110	7.9	0.579	643	57.0
1974	45.2	76859	1700	10.5	0.769	1307	58.7
1975	50.9	79605	1564	12.5	0.916	1433	55.6
1976	44.6	58396	1309	13.2	0.967	1266	46.1
1977	37.4	68538	1833	16.0	1.172	2148	31.9
1978	39.5	57973	1468	27.7	2.030	2980	19.5
1979	31.7	25265	797	24.4	1.788	1425	17.7

(1) Catch per successful night fishing

(2) Normalized by the mean

(3) Effort x normalized catchability

(4) Catch : adjusted effort

(5) Fishing mortality per unit of effort (x 10^5) for the 4Xa purse-seine fishery.

Table 11.

Five year projections of catch at $F_{0.1}$ for 4WX herring using various assumptions concerning the input parameters (see text for details).

OPTION A

POPULATION BIOMASS 20/ 3/81

	80	81	82	83	84	85
1	6954.81	13374.83	13374.83	13374.83	13374.83	13374.83
2	1934.54	23271.38	44784.92	44784.92	44784.92	44784.92
3	51443.25	3349.46	42646.75	82072.12	82072.12	82072.12
4	379107.78	63382.07	3628.96	46179.99	88871.71	88871.71
5	26164.28	294954.50	44273.02	3008.06	38299.90	73706.76
6	4429.02	18123.95	219348.18	32924.42	2237.00	28482.40
7	4918.23	2964.88	13025.28	157640.62	23662.04	1607.68
8	7129.86	3302.27	2137.20	9389.13	113633.50	17056.32
9	3189.22	4645.67	2310.02	1495.02	6567.92	79489.34
10	13838.86	2083.52	3258.34	1620.18	1048.57	4606.55
	499109.87	419452.52	488785.49	392489.28	414852.60	441052.84

OPTION B

POPULATION BIOMASS 20/ 3/81

	80	81	82	83	84	85
1	13370.82	13374.83	13374.83	13374.83	13374.83	13374.83
2	1934.54	44808.53	44817.72	44817.72	44817.72	44817.72
3	130172.22	3349.46	89132.61	89150.89	89150.89	89150.89
4	379107.78	152348.27	3936.94	104766.16	104787.65	104787.65
5	26164.36	294954.51	121446.00	3138.37	83515.43	83532.56
6	4429.00	18124.03	209906.11	86427.76	2233.44	59434.25
7	4918.34	2964.86	12464.64	144361.11	59439.94	1536.03
8	7129.90	3302.37	2045.19	8598.23	99581.70	41002.25
9	3189.19	4645.71	2210.65	1369.07	5755.76	66661.19
10	13838.67	2083.49	3118.11	1483.74	918.90	3863.15
	584254.83	539956.04	502452.79	497487.89	503576.26	508160.52

CATCH BIOMASS 20/ 3/81

	80	81	82	83	84	85
1	20	30	30	30	30	30
2	398	3822	7356	7356	7356	7356
3	8171	122	5372	10349	10349	10349
4	86395	9750	662	8434	16232	16232
5	6529	59169	8881	603	7683	14786
6	1105	3838	41002	6605	449	5714
7	1227	595	2613	31624	4747	323
8	1779	662	429	1884	22795	3422
9	796	932	163	300	1318	15946
10	3453	418	654	325	210	924
	109873	79437	70468	67509	71168	75080

CATCH BIOMASS 20/ 3/81

	80	81	82	83	84	85
1	20	21	21	21	21	21
2	398	4500	4501	4501	4501	4501
3	8171	198	5271	5272	5272	5272
4	86395	32147	831	22107	22111	22111
5	6529	68227	28092	726	19318	19322
6	1105	4192	48554	19999	517	13748
7	1227	686	2883	33393	11749	355
8	1779	764	473	1989	23035	9484
9	796	1075	511	317	1331	15420
10	3453	482	721	343	213	894
	109873	112292	91859	88660	90068	91129

Table 12. 1980 mean weight-at-age for the overall fishery as defined by the present stock definition.

Age	1980 Fishery wt(kg)	Mean July 1969 to 1978 wt(kg)
1	0.0095	0.010
2	0.0355	0.041
3	0.0869	0.112
4	0.1734	0.172
5	0.2207	0.218
6	0.2583	0.254
7	0.3053	0.286
8	0.3330	0.323
9	0.3592	0.354
10	0.3697	0.389
11+	0.4046	

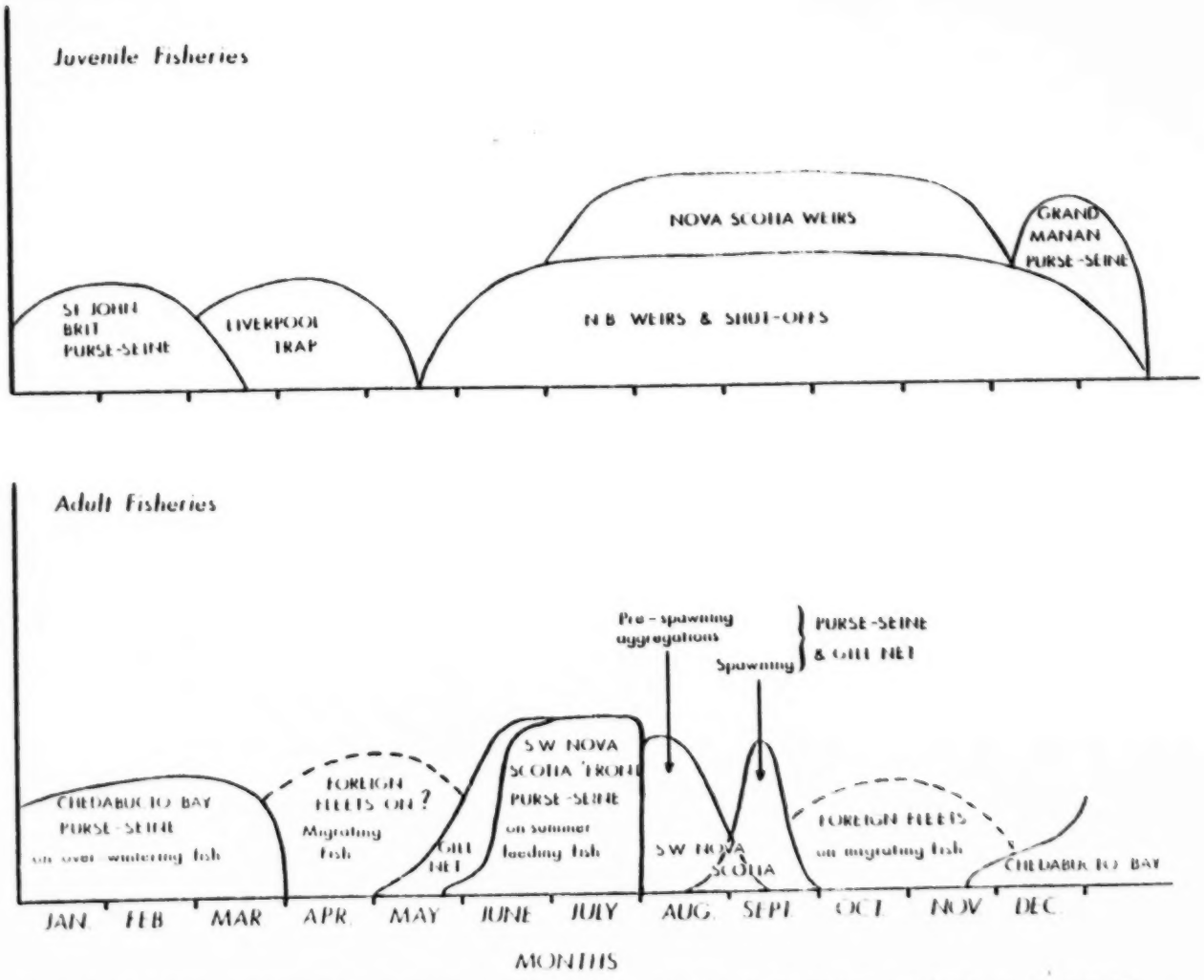


Figure 1. Schematic representation of approximate seasonal distribution of the various components of the juvenile and adult 4WX herring fishery.

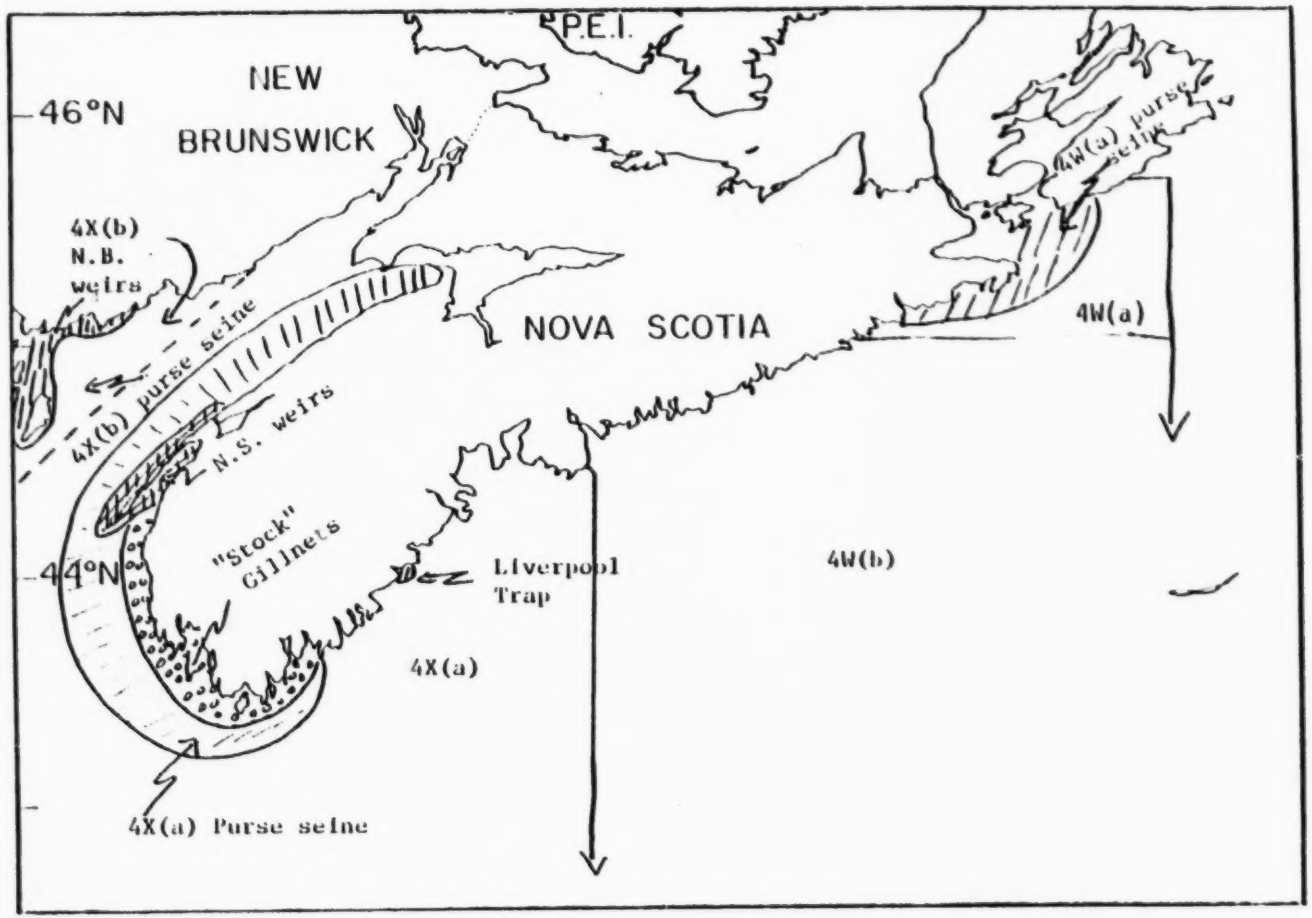


Figure 2. Geographical location of various components of the 4WX herring fishery.

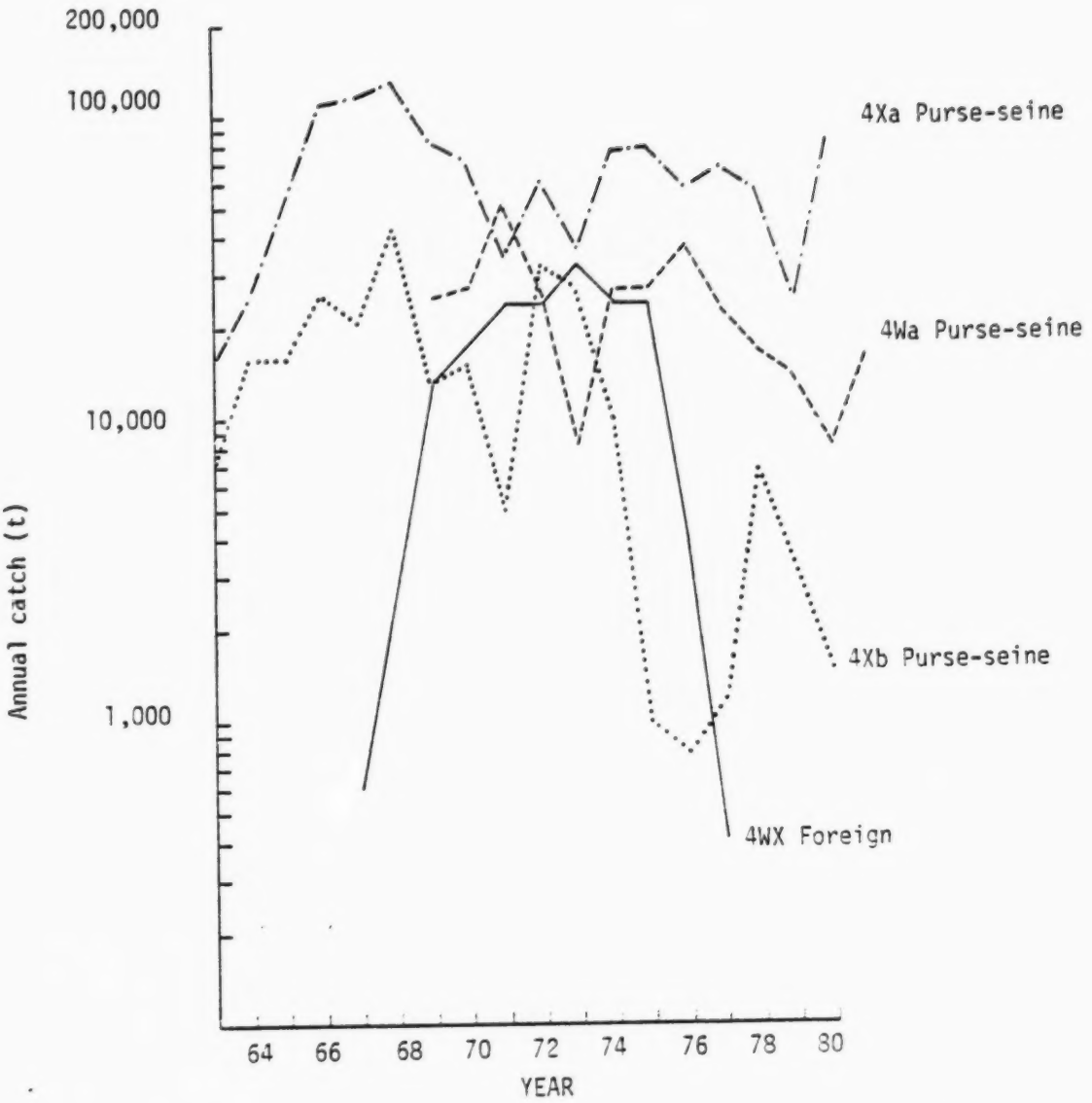


Figure 3. 4WX Mobile Gear Herring Catch (1963 to 1981).

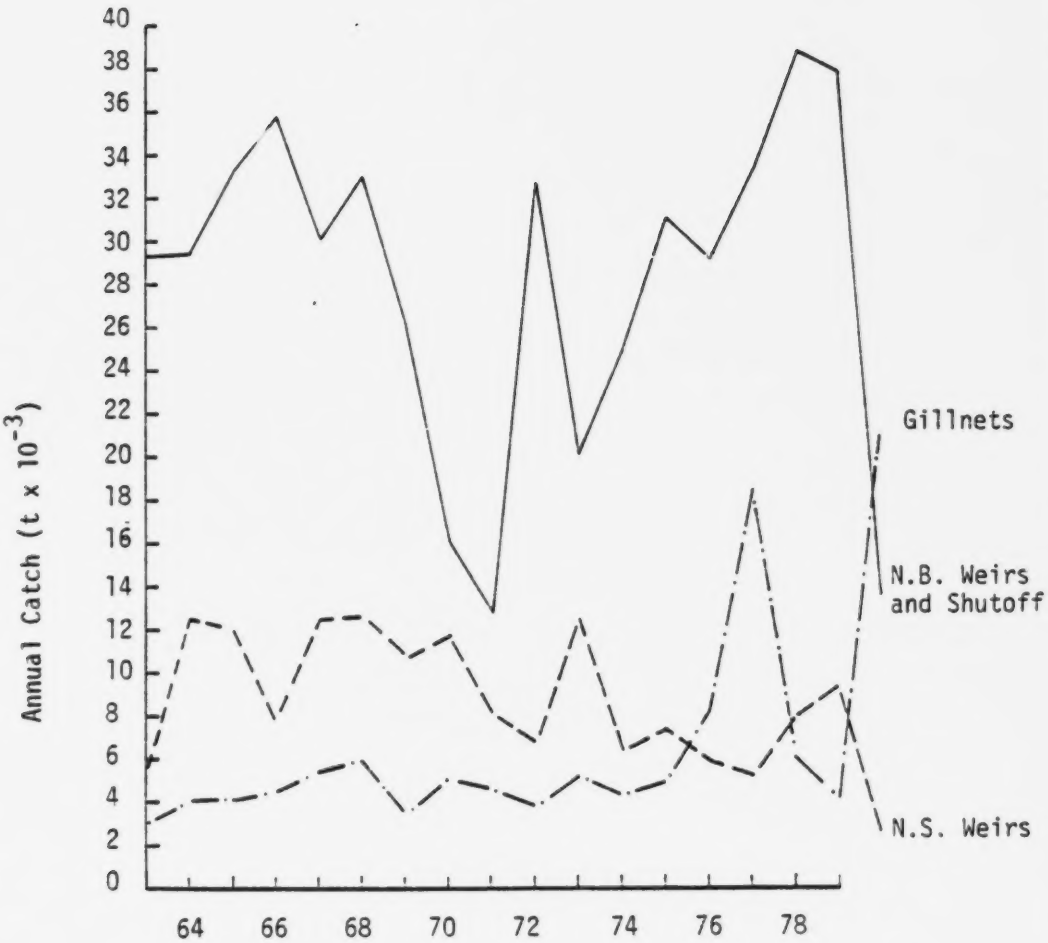


Figure 4. 4X Fixed Gear Herring Catch (1963 to 1980)

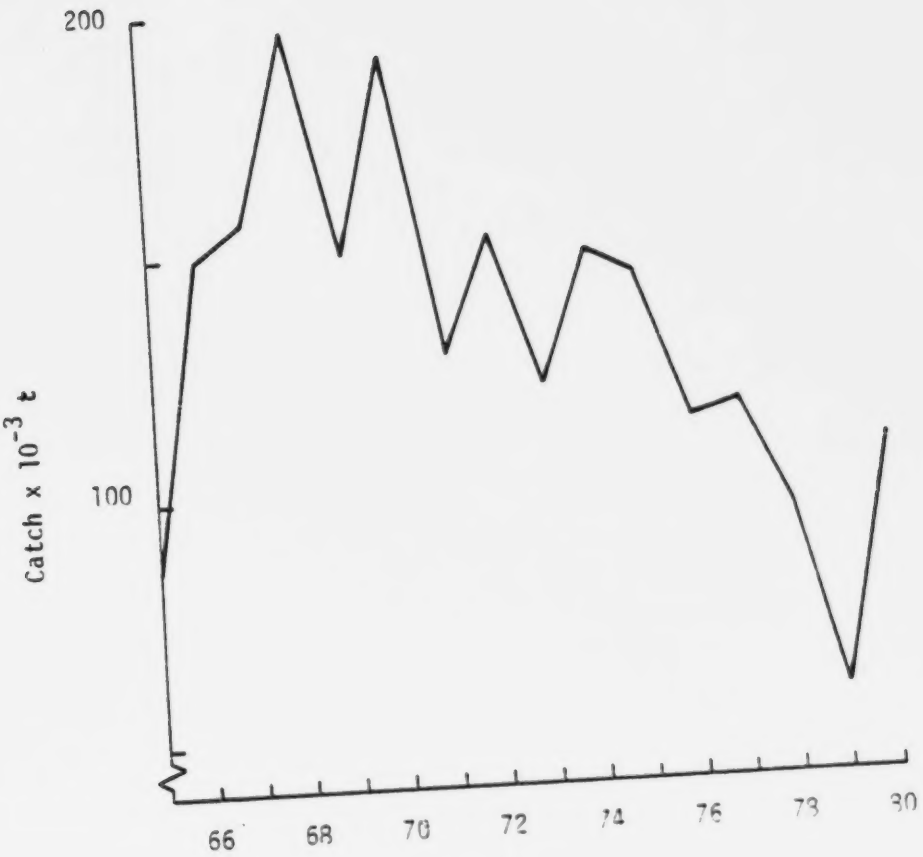


Figure 5. 4WX "Stock" Annual Catch (1965-1980)

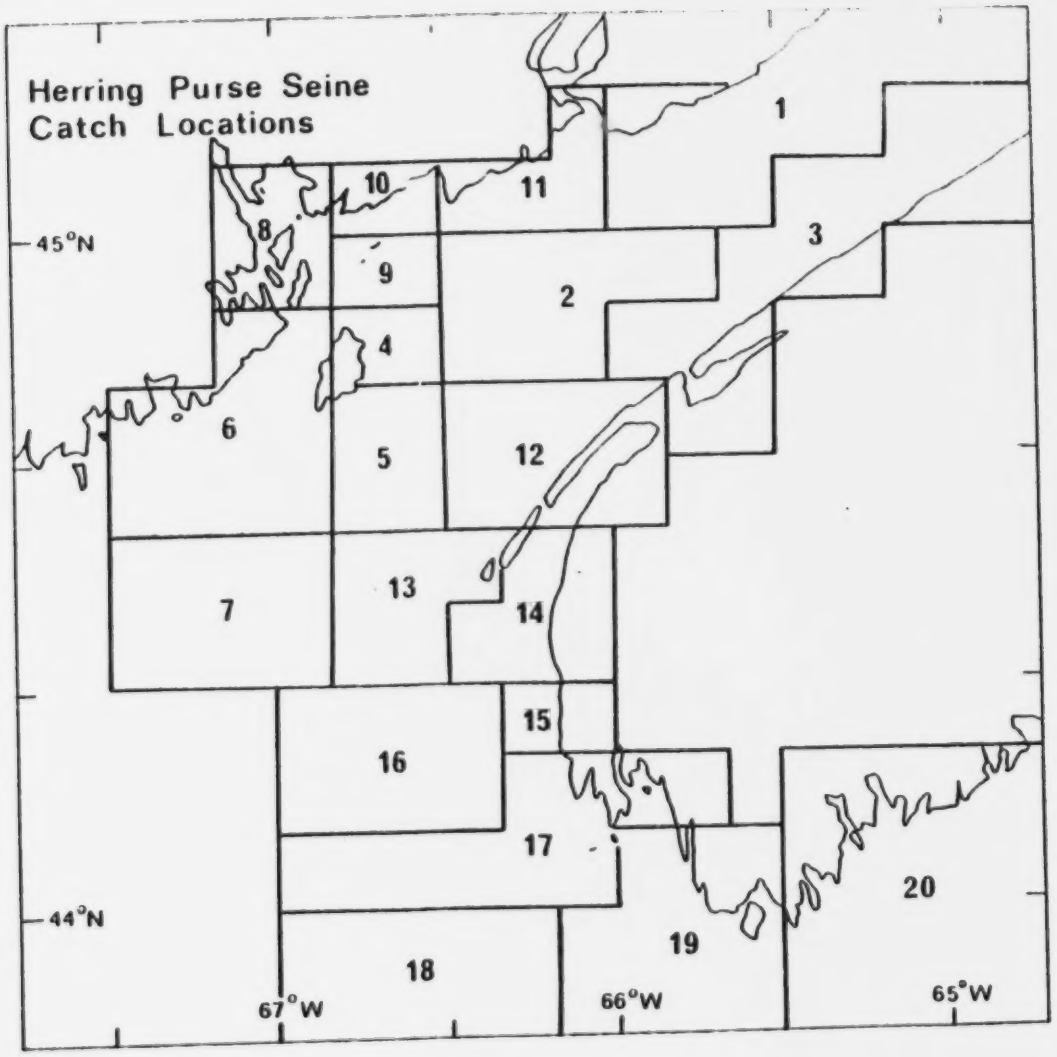


Figure 6a. Herring purse-seine catch locations that are used for the matching of catch and samples for the generation of numbers-at-age.

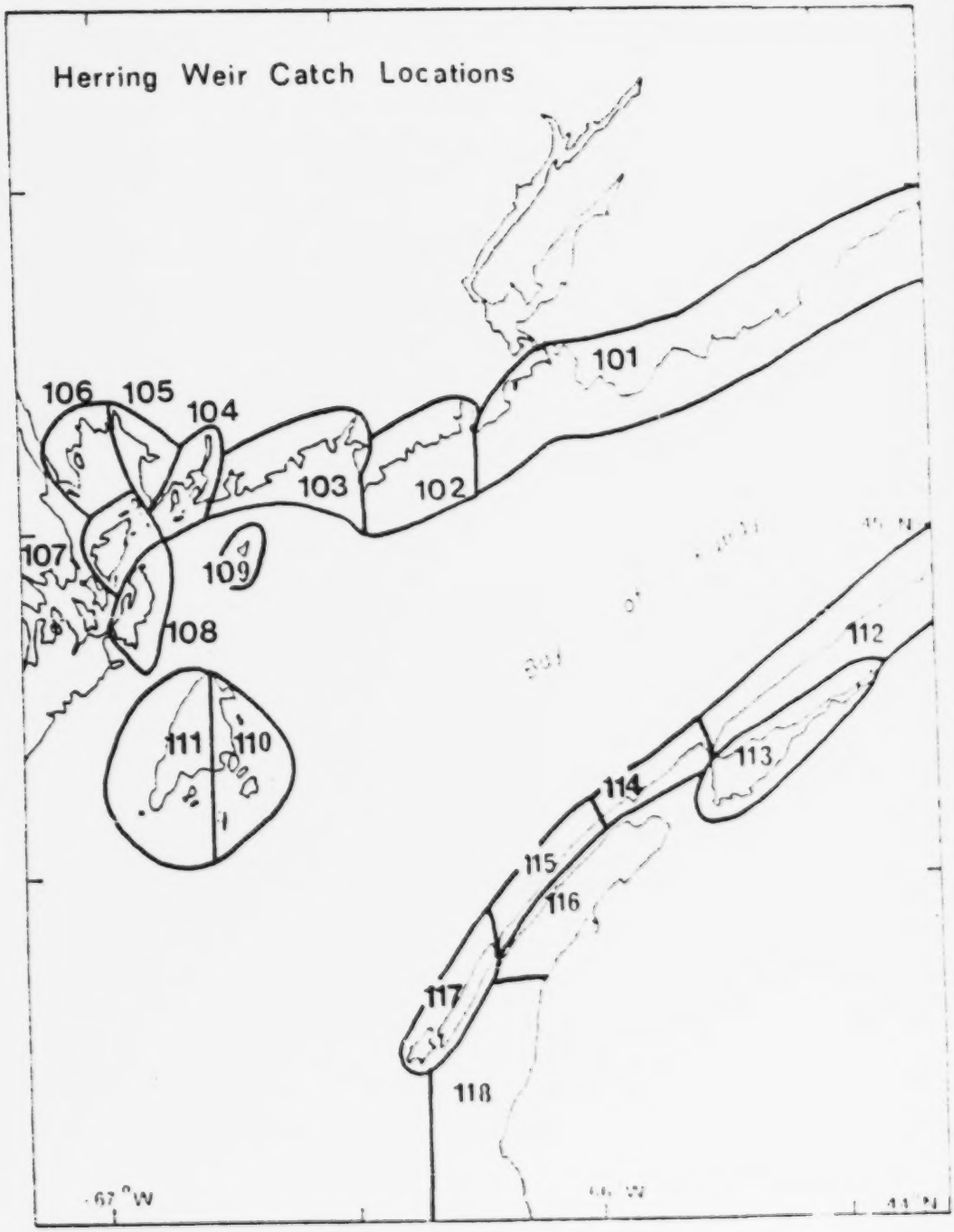


Figure 6b. Herring weir locations that are used for the matching of catch and samples for the generation of numbers-at-age.

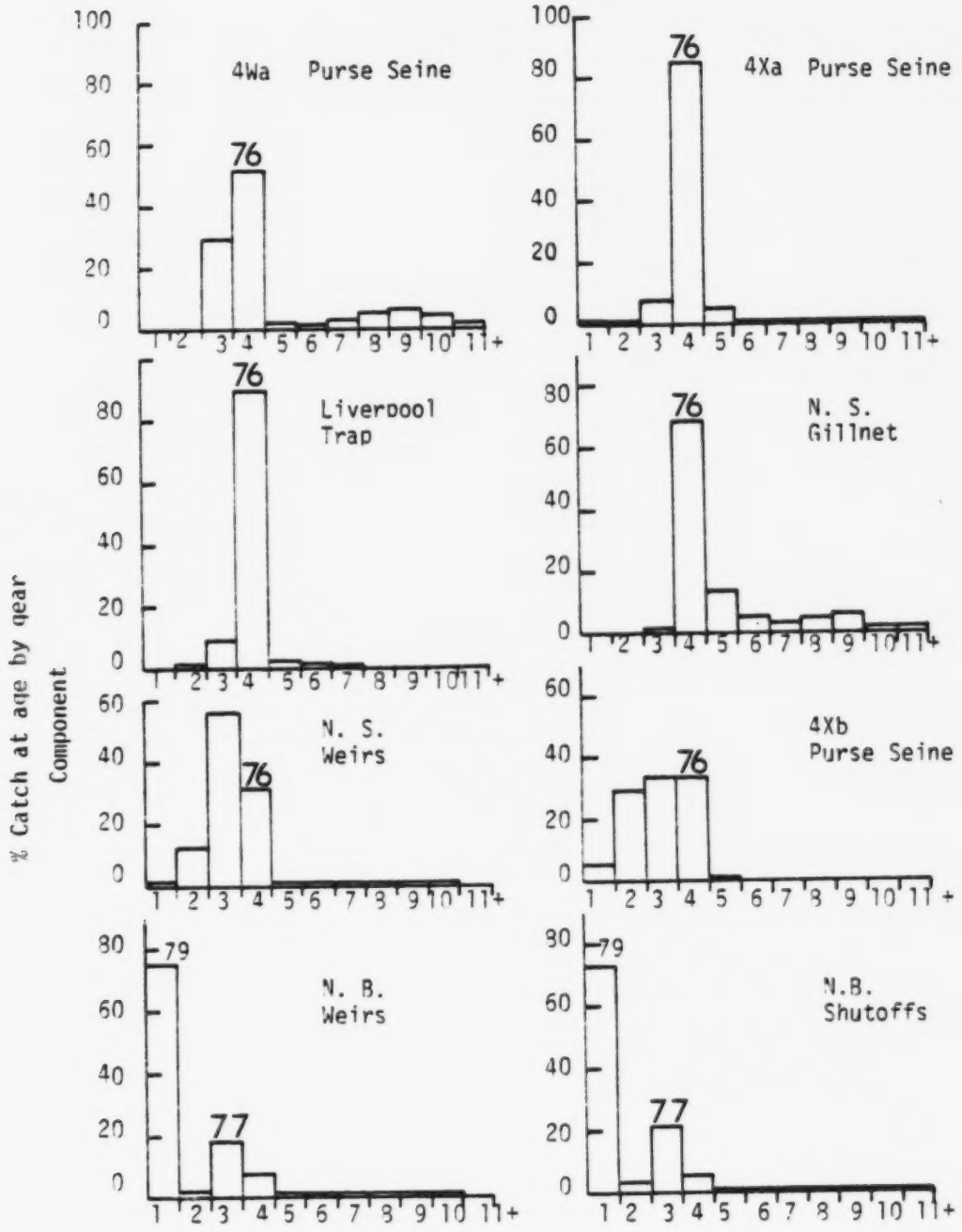


Figure 7. Age composition (%) of various components of the 4WX herring fishery during 1980.

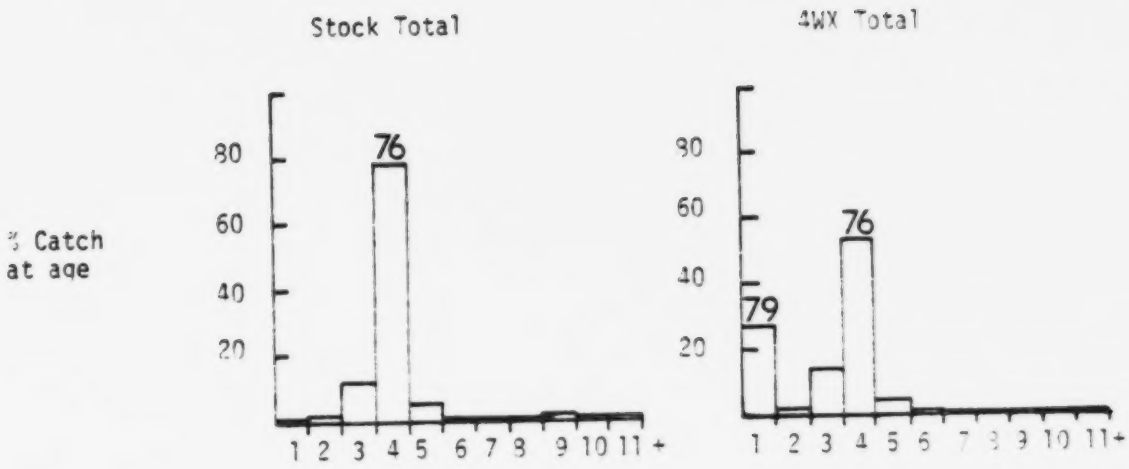


Figure 9. Age composition (%) of the overall 4WX herring fishery during 1980.

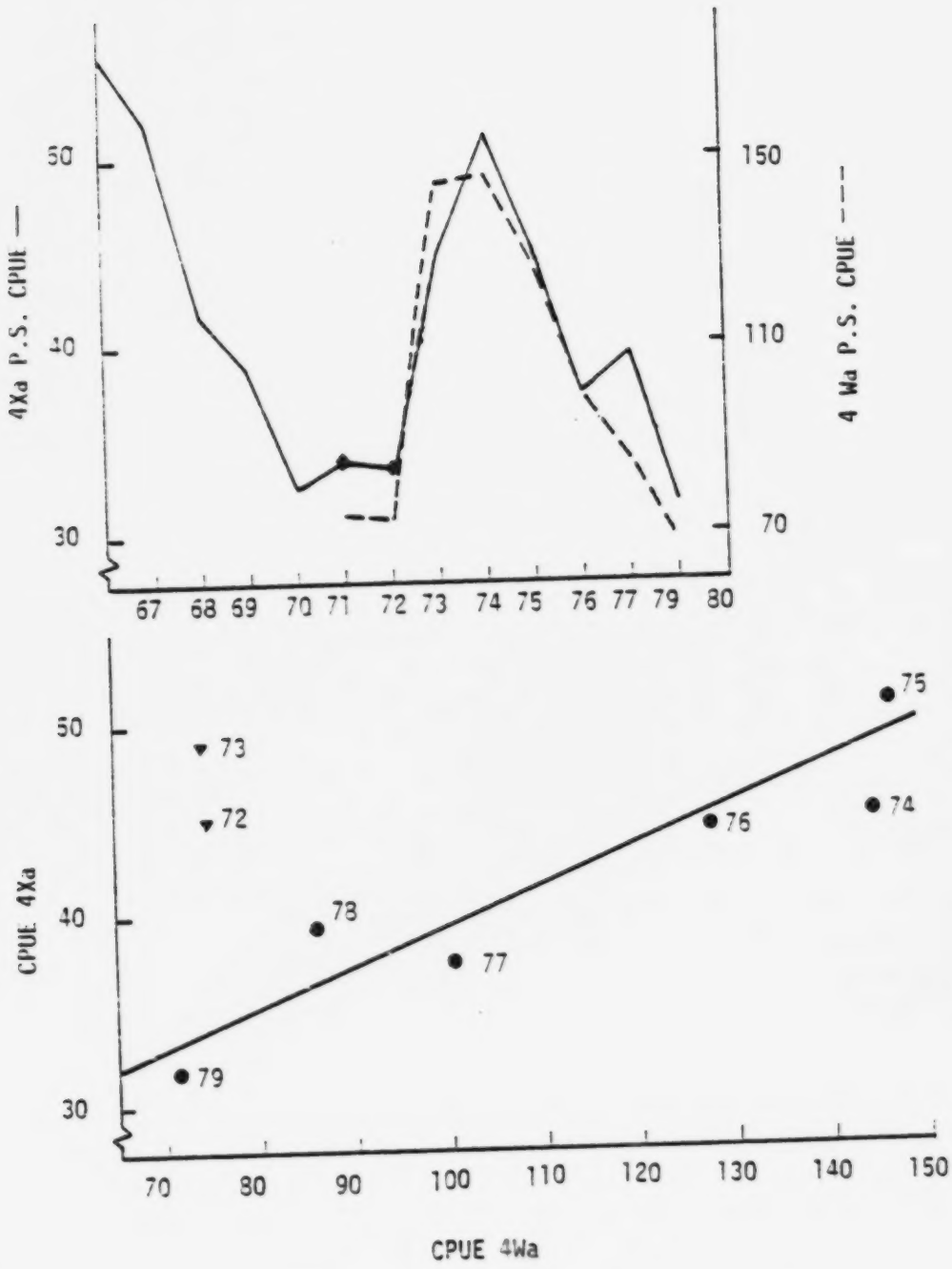


Figure 9. Purse-seine catch rate trends (upper graph), and the relationship between the summer and winter fisheries.

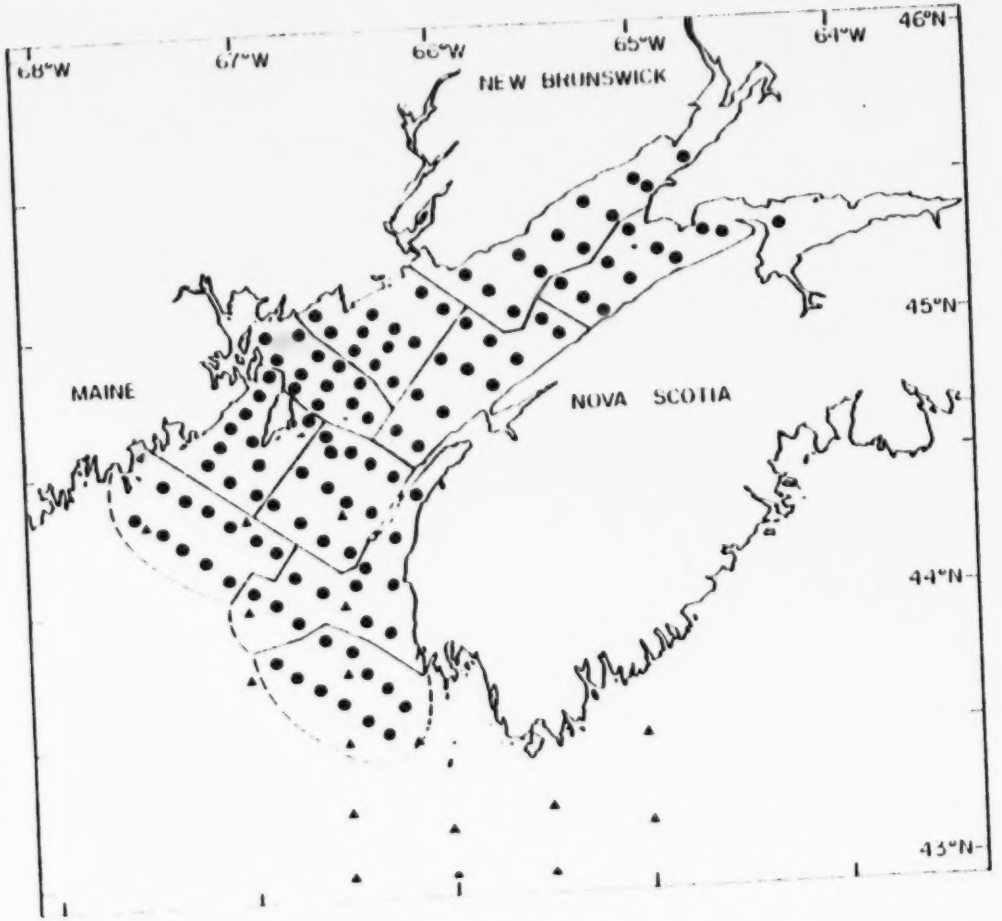


Figure 10. Location of standard sampling stations (circles) for the Bay of Fundy larval survey (triangles represent the ICNAF station locations).

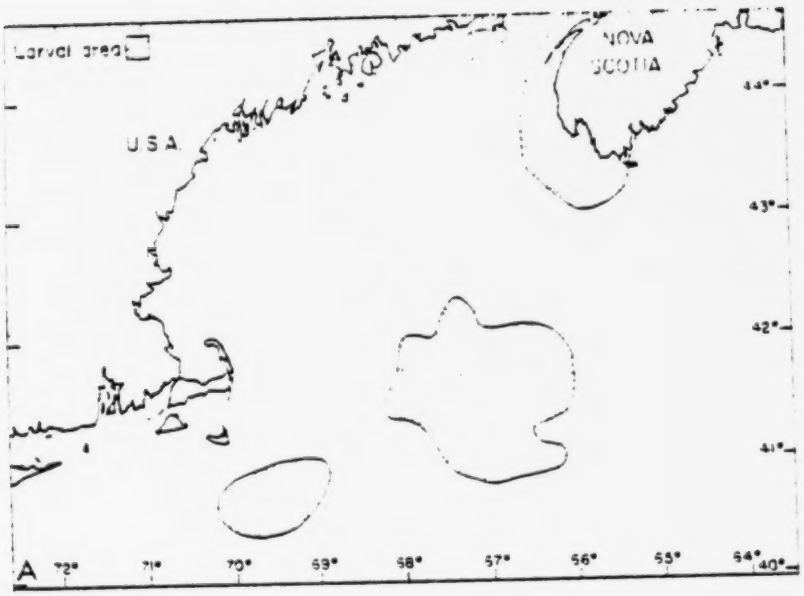


Figure 11. Representative autumn larval distributions for several of the stocks in the Gulf of Maine area.

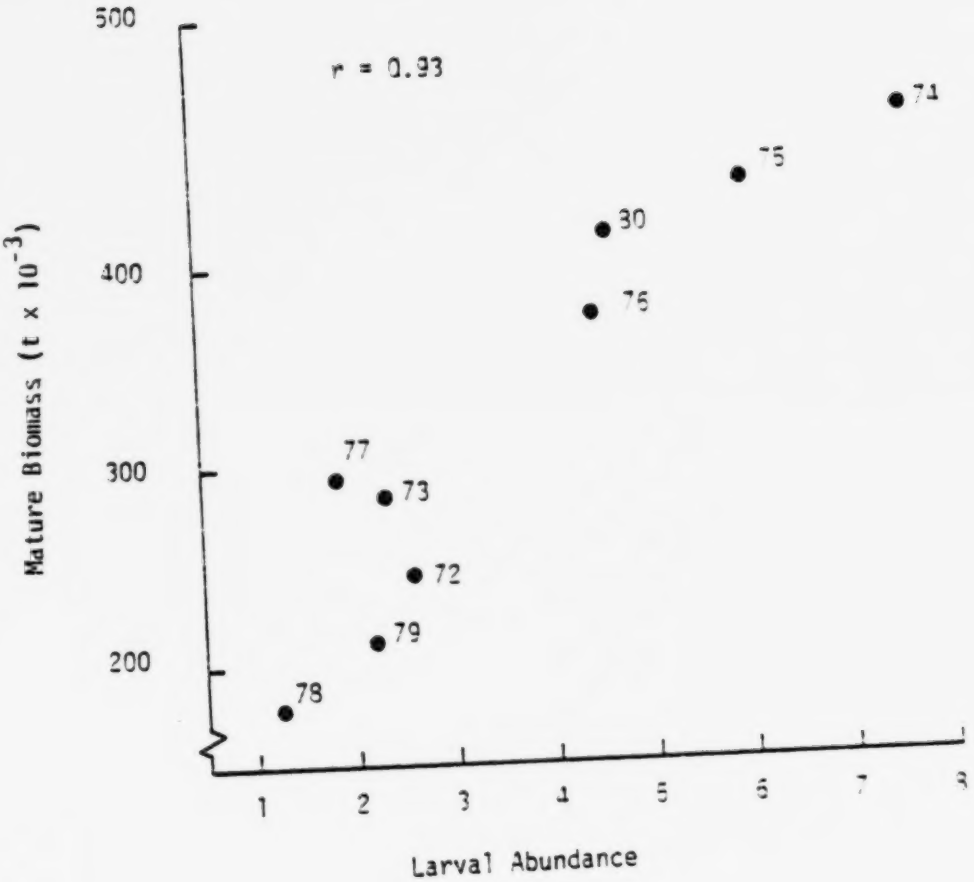


Figure 12. Relationship between mature biomass of 4WX herring and Bay of Fundy autumn larval abundance.

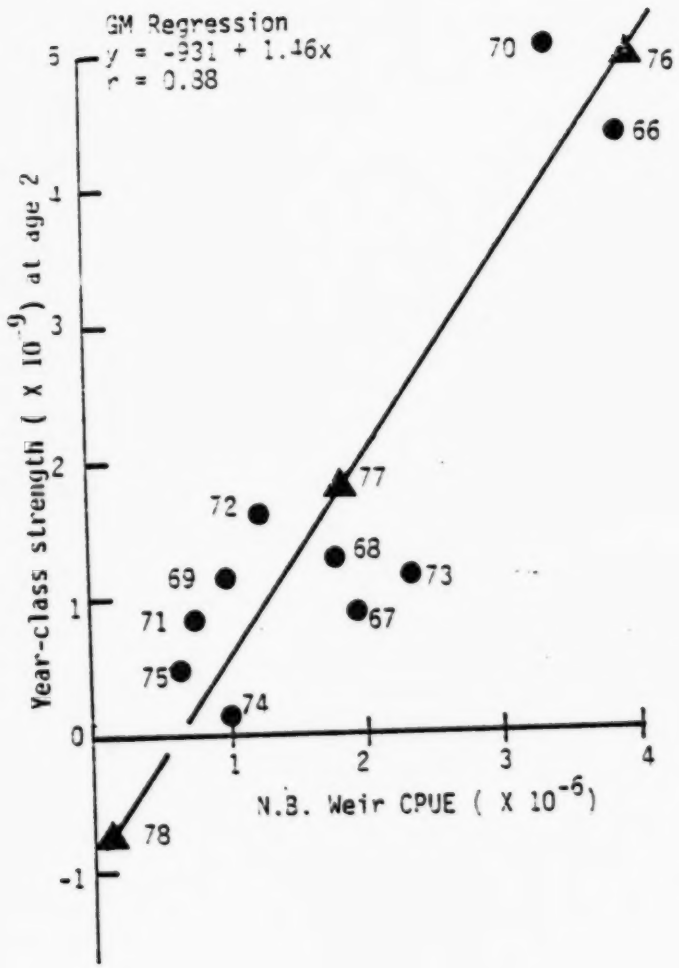


Figure 13. Relationship between 4WX herring year-class strength at age 2 and N.B. weir CPUE.

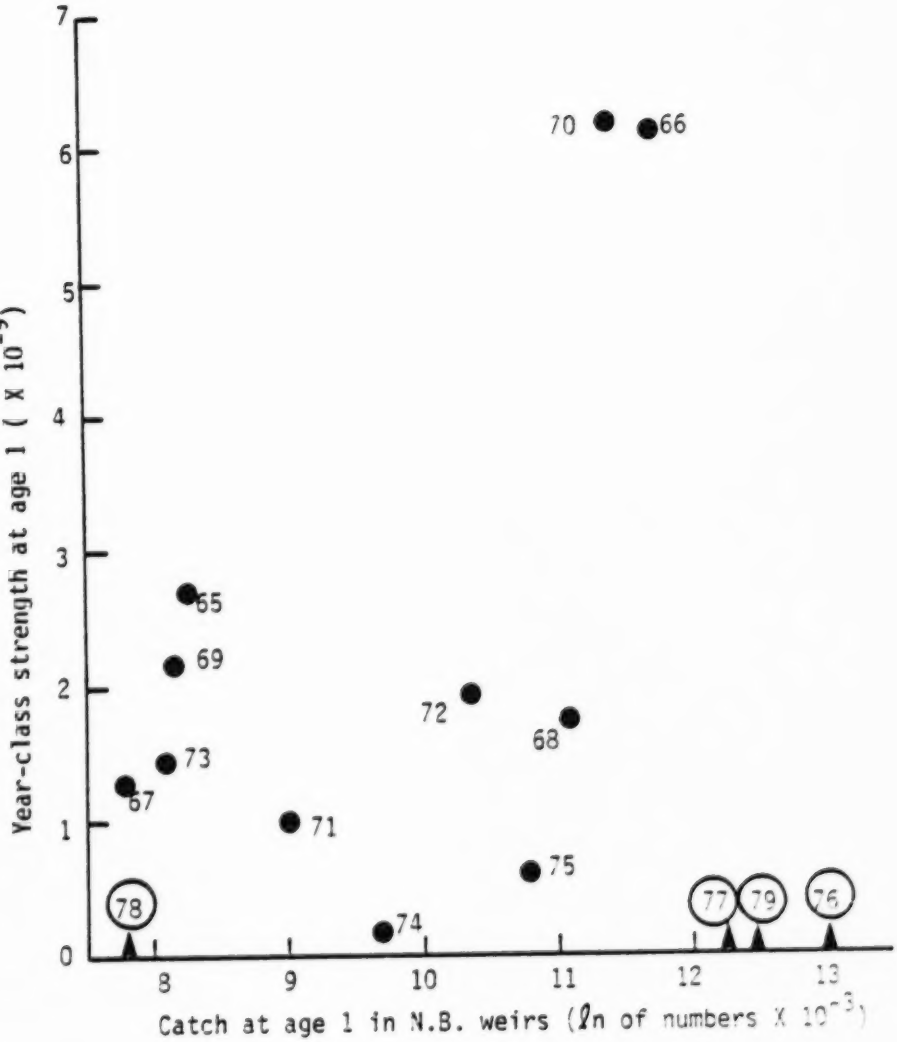


Figure 14. Relationship between 4WX herring year-class strength at age 1 and catch of age 1 fish in N.B. weirs.

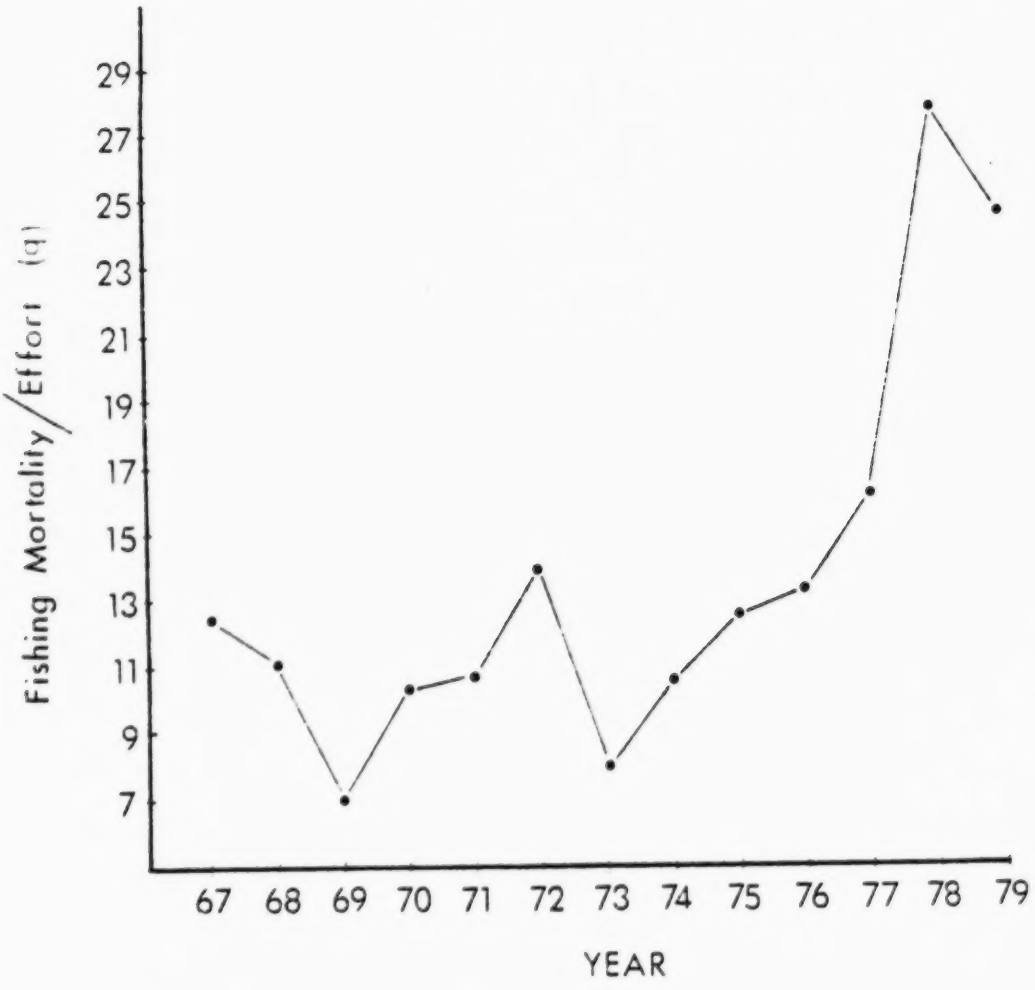
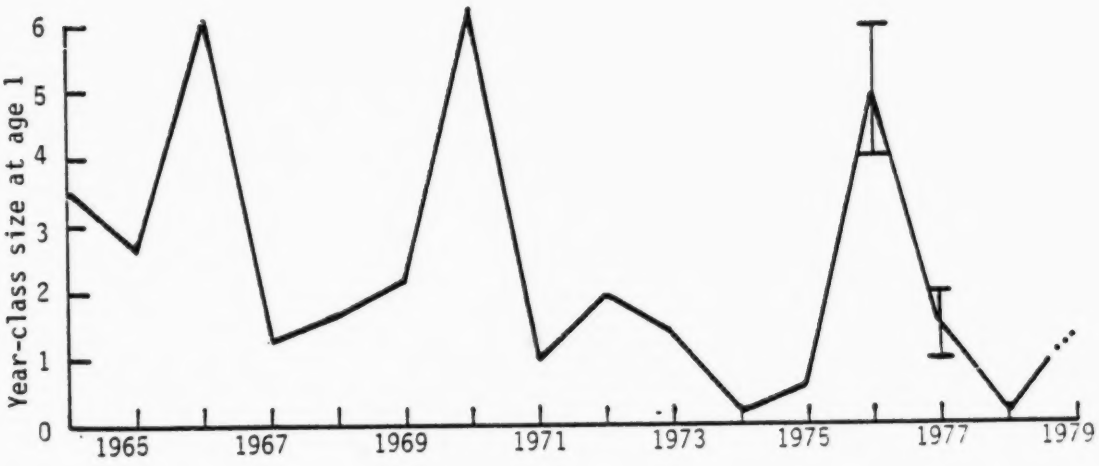


Figure 15. Trends in "q" for the summer purse-seine fishery.



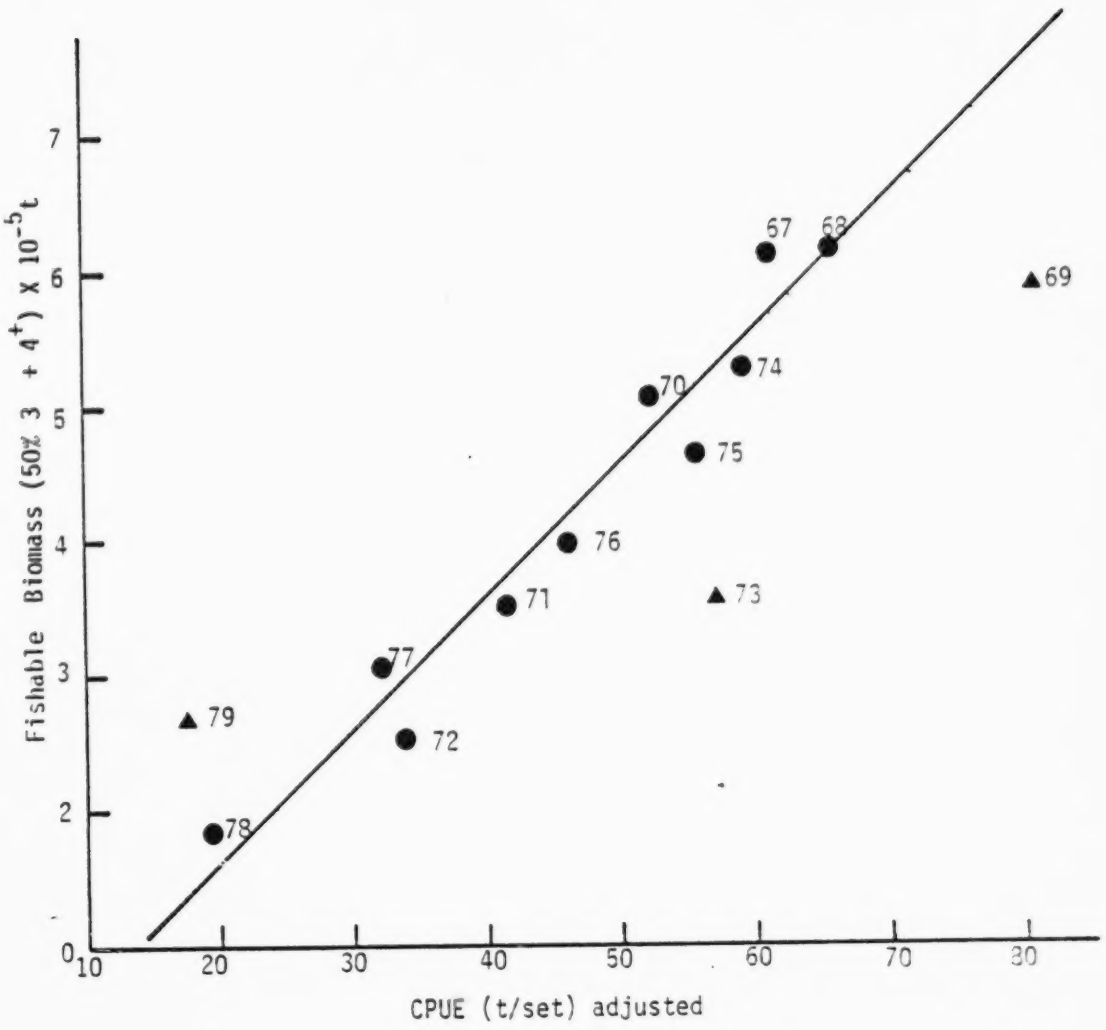


Figure 16. Relationship between 4WX herring fishable biomass and adjusted CPUE (summer purse-seine fishery).

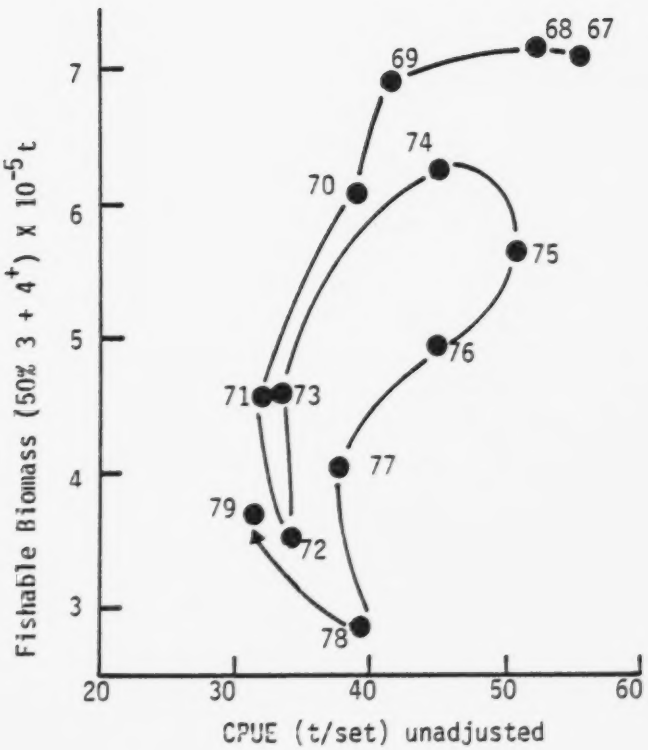


Figure 17. Relationship between 4WX herring fishable biomass and unadjusted CPUE (summer purse-seine fishery).

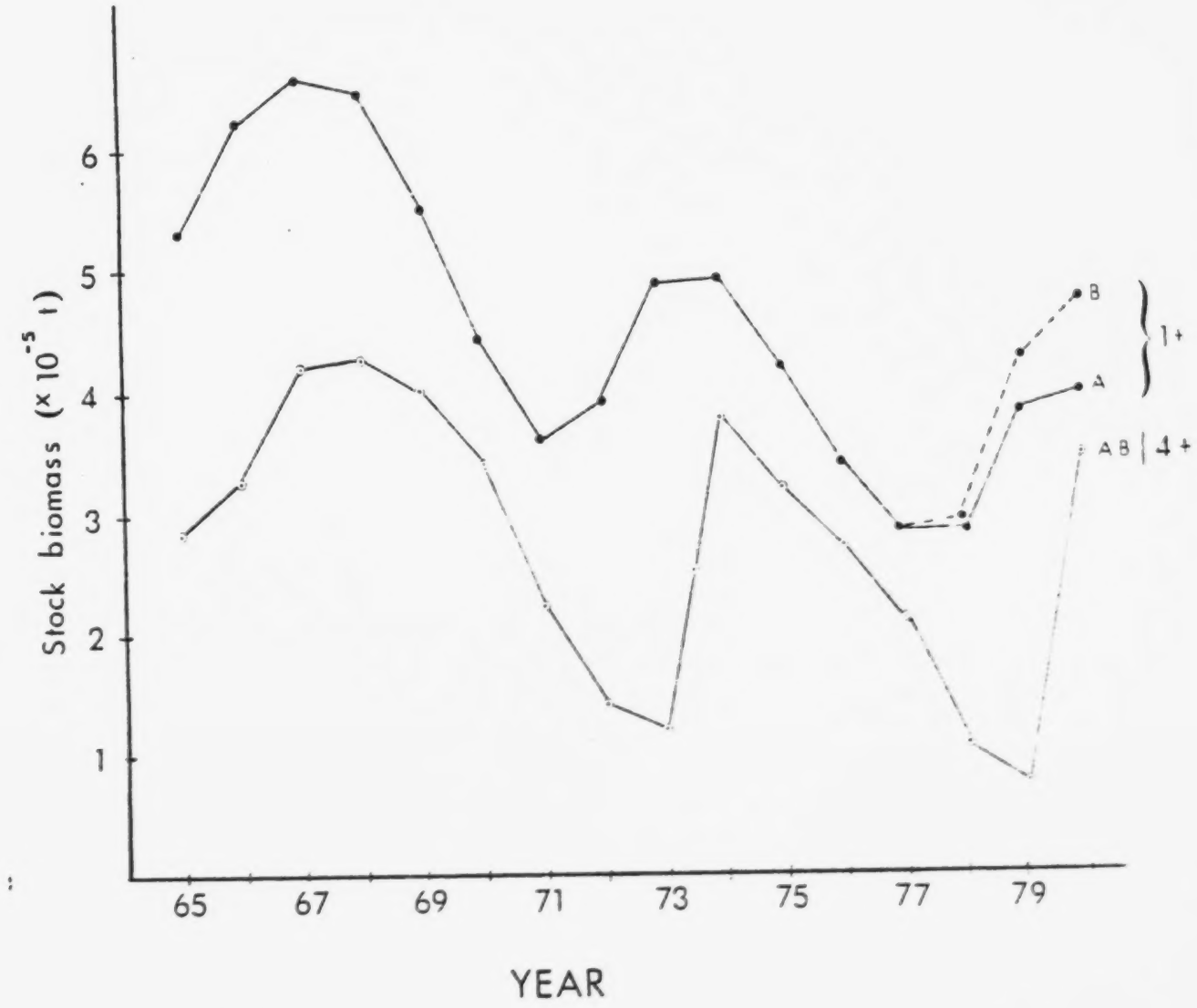


Figure 18. Trends in 4WX herring stock biomass.

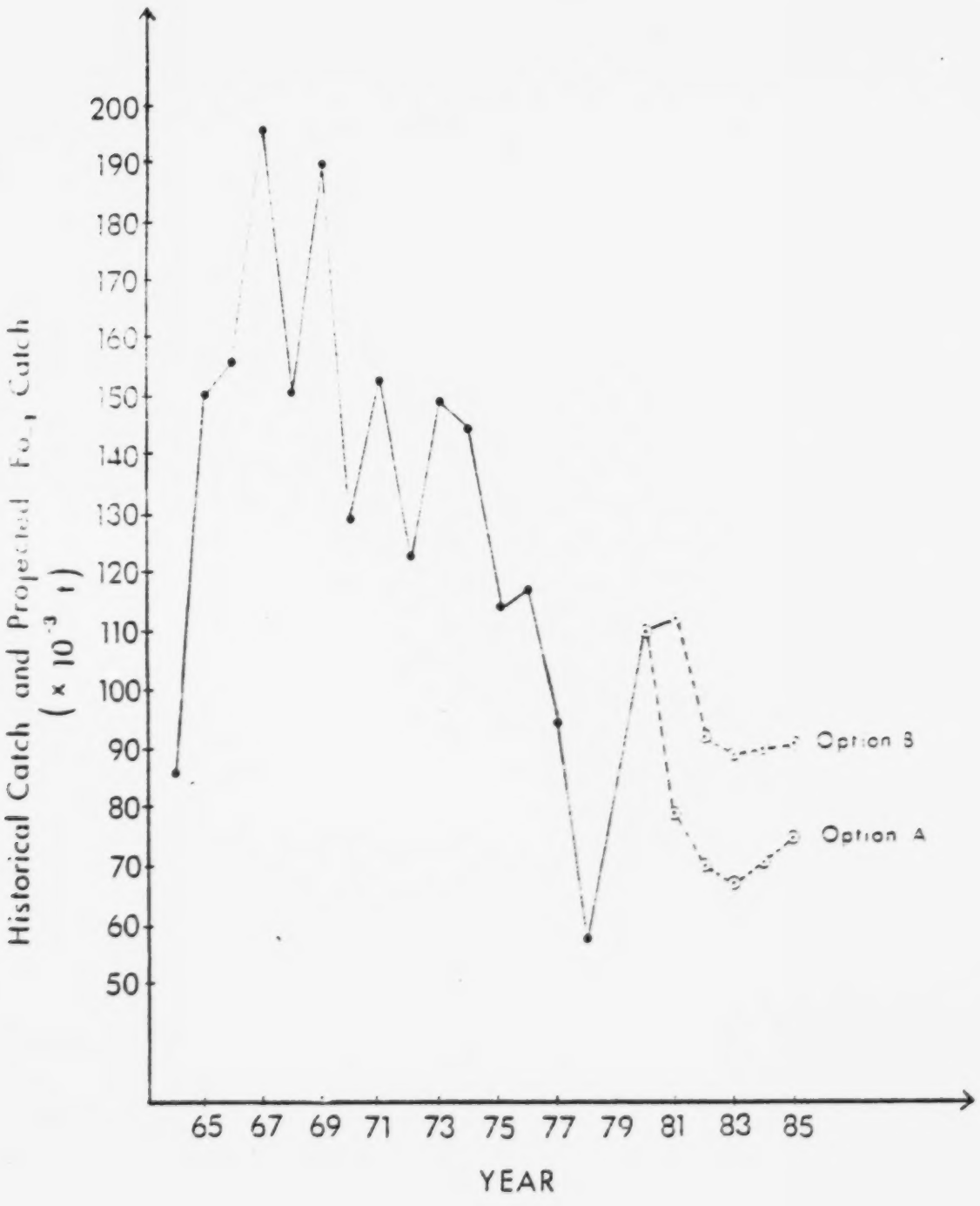


Figure 19. Historical trends in 4WX herring catch and projections (at $F_{0.1}$) to 1985.